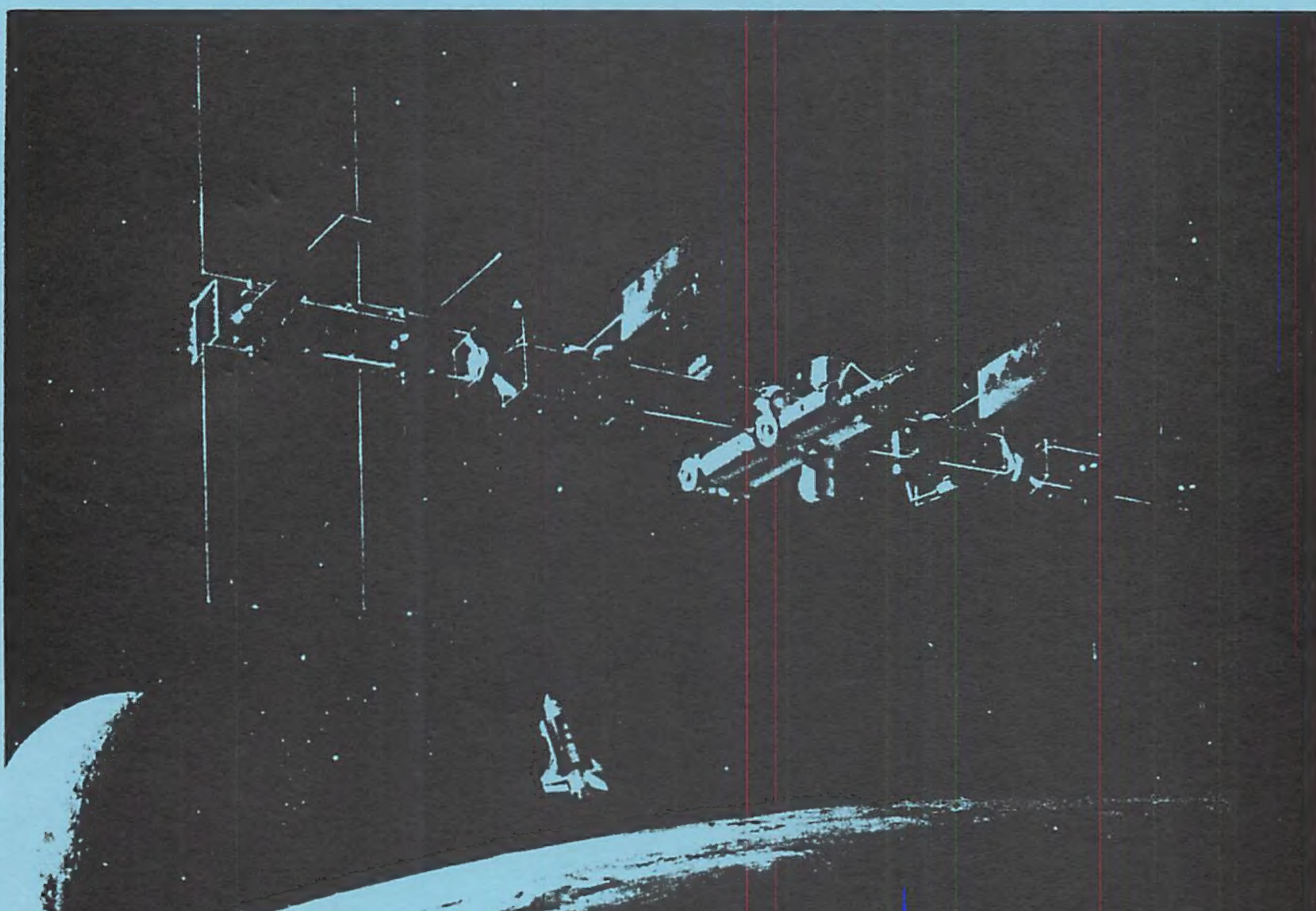
Introduction to Utilizing the Space Station



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Introduction to Utilizing the Space Station

Purpose

The purpose of this *Introduction to Utilizing the Space Station* is to introduce potential users to the capabilities, resources and accommodations of the Space Station Program. It provides information on the various elements of the Space Station Program and discusses how the science, technology and commercial communities can benefit from the use of these elements. A user integration scenario is provided to show the types of activities and milestones a typical investigator may encounter during the payload development and integration process.

Scope

This guide is intended for distribution to a wide selection of potential users (NASA, other Government agencies, academia, industry and commercial) who are interested in flying payloads that make use of U.S.-provided Space Station resources and accommodations. Reference is made to the international elements of the Station; users may have access to a certain percentage of international resources through NASA, but investigators who wish to be sponsored by a Partner should contact the Partner directly.

Though this document will be useful to commercial users of the Station, it does not address the specific needs of commercial developer/operators who will provide Station elements or hardware.

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Suggested revisions to the document should be submitted to the authors, Laura Crary and Randy Cassingham, in care of the Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena CA 91109.

I. INTRODUCTION

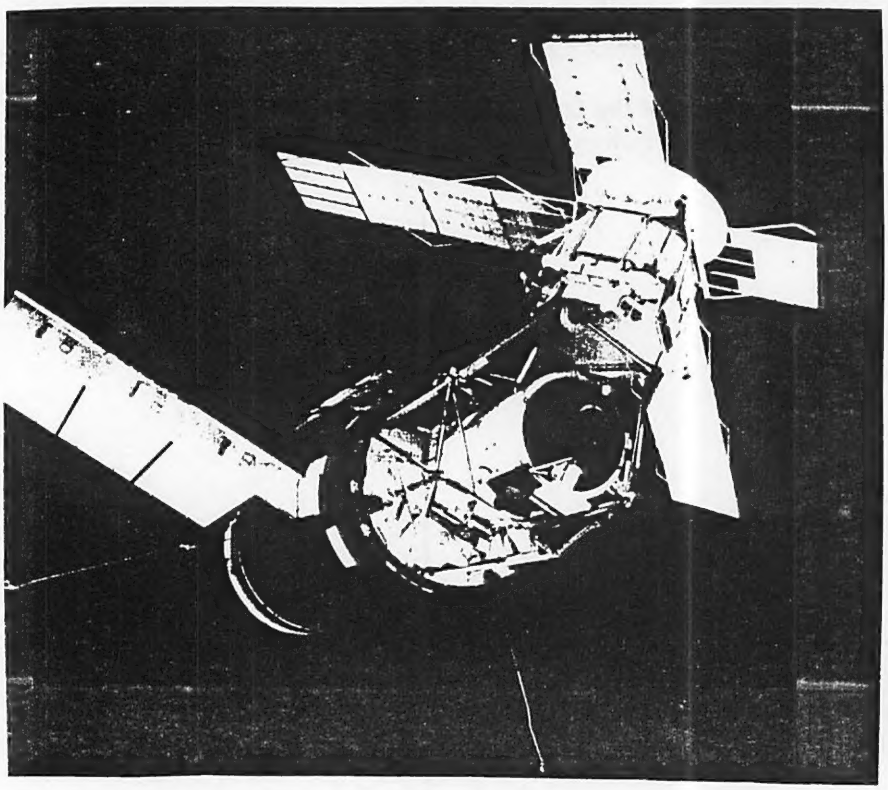
The Space Station is a permanent, manned complex, with associated spacecraft service facilities and unmanned platforms, assembled in space with the support of the U.S. Space Shuttle. Offering both the accessibility to payloads offered on earlier manned flights and the long duration of experiments previously feasible only on unmanned spacecraft, the Space Station creates a unique new opportunity for the conduct of space research.

The Station will be a national laboratory, operated and evolved in response to user interests. These users will come from the commercial sector, the technology development community, and the science and applications community, both domestic and international.

The Space Station will be operational in the 1990s. Plans for user participation in the Program should begin now, as NASA's intention is to utilize the Station's unique environment to the fullest extent possible for the conduct of science and the development of new technologies. This document is the first step for those individuals who are interested in using the Space Station.

Background

The idea of a space station has been the subject of NASA studies dating back to the 1960s. In the early 1970s, scientists and crew aboard the first U.S. space station, Skylab, performed experiments in long duration, manned space flight. However, Skylab was not equipped for resupply of key expendable items, and consequently could not be used over a multi-year period.



A closeup view of the first U.S. space station — Skylab — in orbit. This photo shows Skylab 3 as it appeared to the crew as it approached for docking. The Skylab 3 mission lasted 59 days.

Plans for a space station supported by a reusable space shuttle were formalized in 1970, but the space station was deferred pending development of the shuttle, which became operational in 1982. In 1984, NASA was mandated by the President to permanently occupy a space station "within a decade", and work began on the design, development and deployment of a permanent facility that would provide a sustained, evolutionary commitment to manned presence in space.

A number of designs for the Space Station have been suggested and studied by NASA and industry. From the beginning, the goal of the Space Station Program has been to design the Station to accommodate user needs rather than to launch a facile design that users would have to adapt to. The current configuration is a modular system that will begin modestly and grow in capability and size to satisfy Program requirements as they evolve over time.

Program objectives

The main objectives of the Space Station Program are critical to realizing the goal to assure U.S. leadership in space and the goals outlined by the National Commission on Space. These objectives are:

- to enhance and evolve mankind's ability to safely live and work in space
- to establish a permanently manned Space Station in Earth orbit by 1996
- to stimulate technologies of national importance (especially automation and robotics) by using them to provide Space Station Program capabilities
- to provide affordable and continually improving facilities for scientific, technological and operational activities enabled or enhanced by the presence of man in space
- to promote substantial international cooperative participation in space
- to provide for the evolution of the Space Station Program to meet future needs and challenges.

Space Station Program organization

The Space Station Program is managed by NASA using a tiered management structure, led by the Office of Space Station. The Office of the Associate Administrator for Space Station is referred to as Level I, and has responsibility for overall program and policy direction consistent with direction from the NASA Administrator. Level II, the Space Station Program Office (SSPO), is responsible for developing the Program as a whole. Responsibility for development of individual elements and distributed systems of the Program rests with Level III, composed of the project offices located at five NASA field centers: Kennedy Space Center, Marshall Space Flight Center, Johnson Space Center, Goddard Space Flight Center, and Lewis Research Center. The Program is also supported by Ames Research Center, Langley Research Center, the National Space Technology Laboratory, and the Jet Propulsion Laboratory.

Internationally, the Space Station Program is supported by the Program's Partners: the European Space Agency, the Japanese Science and Technology Agency, and the Canadian Ministry of State for Science and Technology. International cooperation is leading to an expansion of the capabilities of the Space Station and the prospect of even greater cooperative space ventures in the future. This international participation is encouraged through arrangements between NASA and the Partners that ensure a broad distribution of technical, scientific, and commercial opportunities. Investigators who need detailed information about a Partner's Space Station elements or resources should contact the Partner directly (see Appendix 4).

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Space Station Program organization.

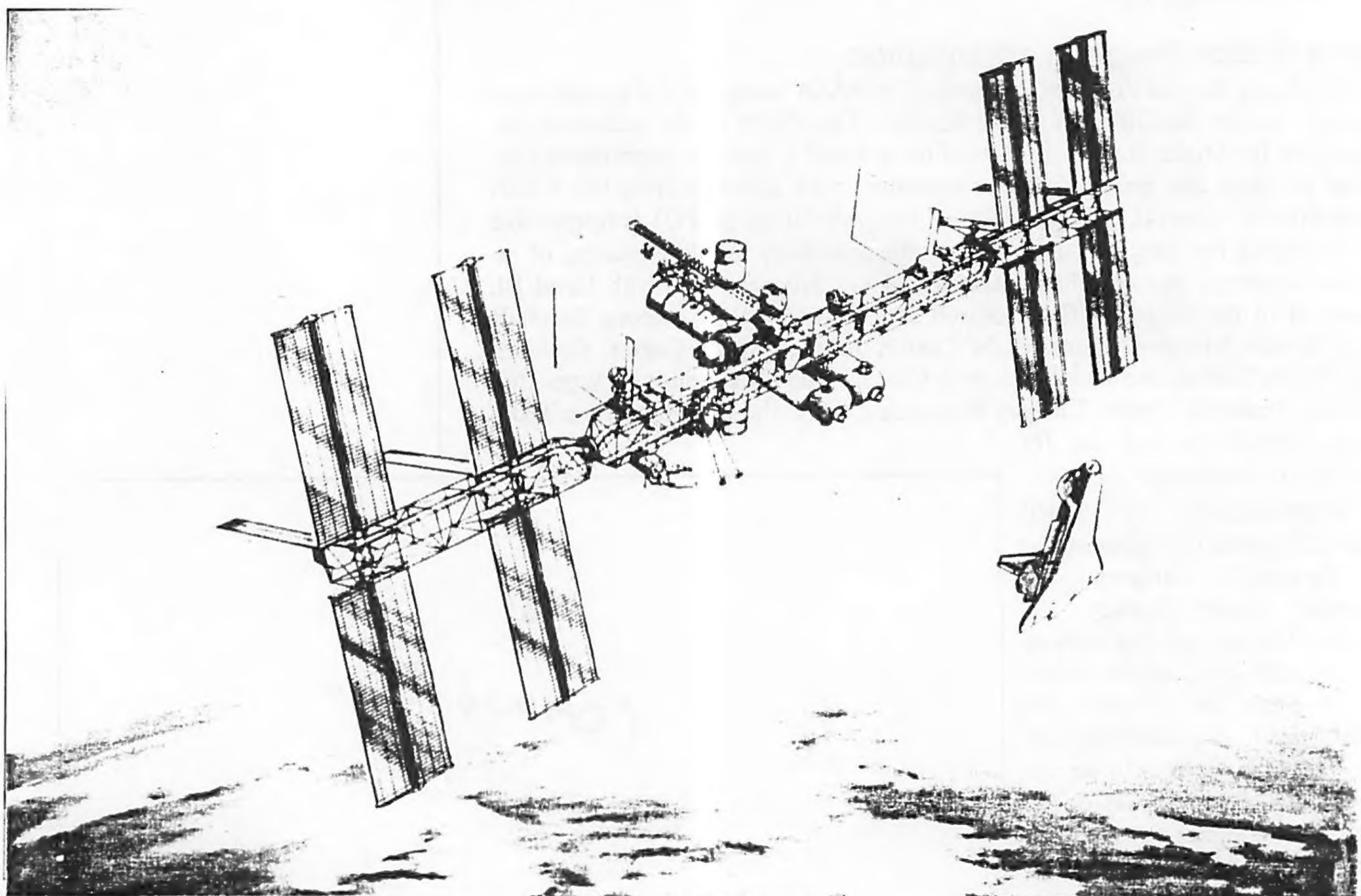
II. THE SPACE STATION

General description

As announced in April of 1987, the Space Station is to be built in two main phases. Phase I consists of the construction and operation of a manned base orbiting Earth at an altitude of approximately 220 nautical miles, two polar-orbiting Platforms, and associated ground-based facilities. Phase II will expand the Space Station to a dual keel configuration, providing enhanced capabilities through evolutionary growth.

Phase I

The major physical elements of the Phase I configuration provided by the United States include pressurized habitation and laboratory modules for conducting experiments in the microgravity environment, accommodations for attached



The baseline "Phase I" Space Station configuration.

payloads, the flight telerobotic servicer (FTS), logistics elements, and a polar-orbiting Platform. The ground-based infrastructure needed for Space Station operations, including facilities for mission control, launch processing, and training and testing, will also be provided.

The Phase I configuration also includes elements provided by the Program's international Partners. These include the Japanese Experiment Module (JEM), a Japanese-supplied experiment logistics module, the initial phase of the Canadian mobile servicing system (MSS), and ESA's Columbus laboratory module and unmanned polar-orbiting Platform.

The Phase I Station features a 360 foot horizontal boom which supports the manned core modules, power and cooling systems, external payloads, and supporting systems. The four pressurized modules of the Station are linked by resource nodes, which are passageways outfitted with racks providing extra space for equipment. Photovoltaic power modules supplying a total of 75 kw are located at either end of the boom. Attachment points for external payloads are also provided along the boom.

Phase II

The Space Station is designed to facilitate evolution. Specific design provisions ("scars") have been incorporated to allow increases in resources and the addition of new functional capabilities to accommodate a changing user community. Several options are under study. The current "reference option" for Phase II, the enhanced capabilities phase of the Program, will augment the Phase

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The enhanced capability "Phase II" Space Station configuration.

I configuration by adding side keels and upper and lower booms for increased attached payload accommodations, a satellite servicing facility, a co-orbiting Platform, and accommodations for a Station-based orbital maneuvering vehicle (OMV). Power levels will be boosted by the addition of a "solar dynamic" power system – a solar-heated turbo-generation system. Also, the thermal control system will be enhanced to provide greater heat rejection.

Flexibility for growth will be a major factor in future decisions affecting Space Station configuration. Evolution of the Space Station will result in both quantitative changes in capability (such as an increase in power generation level) and

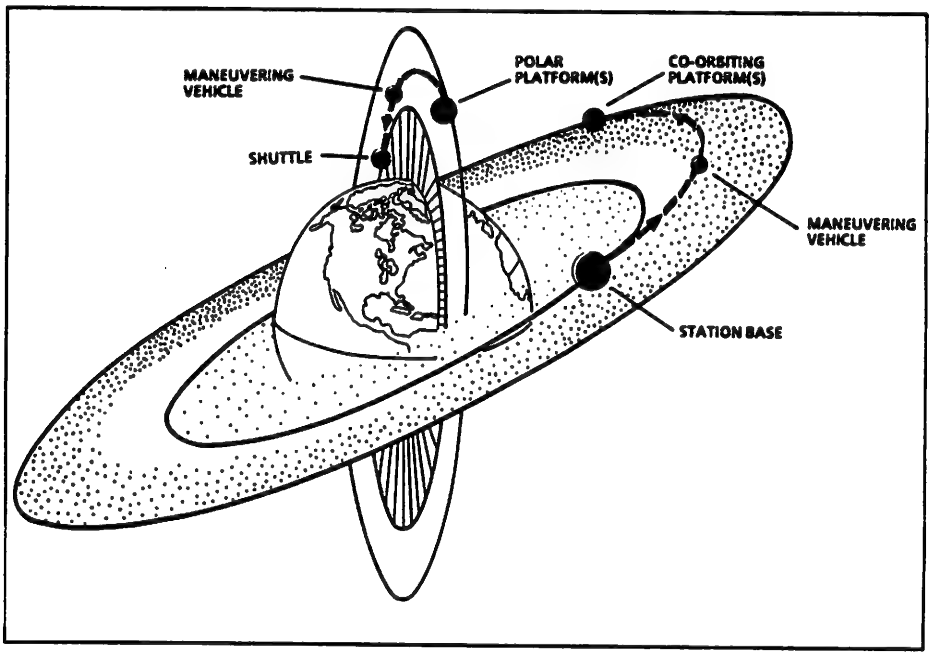
qualitative changes leading to new functional capabilities. Whenever possible, system and subsystem designs will facilitate the incorporation of new technologies.

Space Station Program Elements

The Space Station complex consists of three primary Space Station Program Elements. The first and most widely discussed Program Element is the manned "core" or base – in fact, there is a tendency to think of the base as "the Space Station." The other two Program Elements, the polar-orbiting and co-orbiting Platforms, are also vital components of the Program.

The manned base

The manned base or "core" comprises all the Partner-supplied manned elements of the Program. This includes the various modules, facilities and supporting structures, which are referred to as Space Station Elements. Each of these Elements, with the exception of parts of the Mobile Servicing System and the Maintenance Depot, will be included in the Phase I configuration. These Elements are:



Relative orbits of the Space Station Program Elements.

U.S.-Provided Elements (Pressurized)
- Habitation module
- Laboratory module
- Resource nodes (4)
- Airlock
- Hyperbaric airlock
- Logistics elements

U.S.-Provided Elements (Unpressurized)
- Truss assembly
- Mobile transporter (MSS Base)
- Flight telerobotic servicer (FTS)
- Attached payload accommodations
- Servicing facility
- Power generation facilities
- Propulsion modules
- Logistics carriers

Partner-Provided Elements (Pressurized)
- Columbus module (ESA)
- Japanese Experiment Module (Japan)
- Experiment logistics module (ELM) (Japan)

Partner-Provided Elements (Unpressurized)
- Mobile servicing system (MSS) (Canada)
- MSS maintenance depot (Canada)
- Japanese Experiment Module's exposed facility (Japan)

Orbit parameters

The Station and the co-orbiting Platform will be established in low-Earth orbit (LEO) at inclinations near 28.5 degrees. This inclination serves two purposes: the majority of missions planned for the Station can be accommodated at

Orbit Parameters

Station Base Orbit Parameters (at completion of construction)

- Operational Altitude: 180-270 nmi (290-430 km)
- Inclination: 28.5 degrees
- Orbit Shape: Circular
- Drag (maximum): 0.2 x 10 (-6) g
- Reboost: approx. 90 day intervals
- Orientation: torque equilibrium attitude
- Deadband: 5 degrees peak-to-peak
- Knowledge: .01 degrees, 3 sigma

Co-Orbiting Platform Orbit Parameters

- Operational Altitude: 250-540 nmi (400-860 km)
- Inclination: 28.5 degrees
- Orbit Shape: Circular

Polar-Orbiting Platform Orbit Parameters

- Orbit type: Sun synchronous
- Operating Altitude Range: 310-560 nmi (500-900 km)
- Inclination: 98.7 degrees
- U.S. Platform: Ascending node at 1300-1400 h local time
- ESA Platform: Descending node at 0830 to 1030 h local time

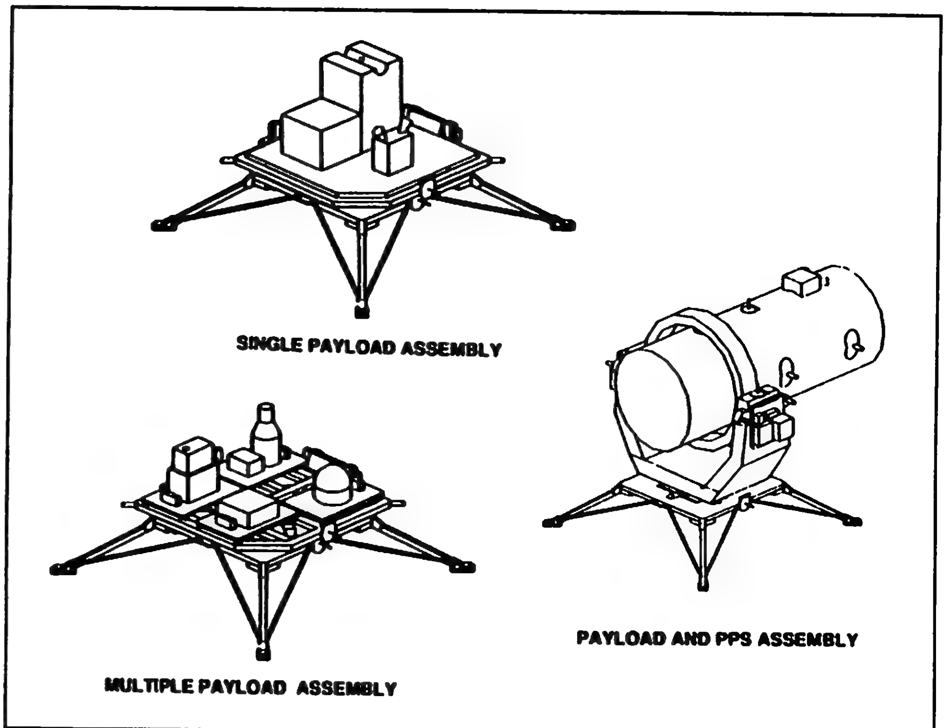
this inclination, and 28.5 degrees is the inclination to which the maximum payload can be delivered by the Space Shuttle. The polar Platform will be in sun-synchronous, low-Earth orbit at a near-polar inclination of about 98.7 degrees.

Attached payload outfitting

Payloads attached externally to the Station base structure are accommodated by at least two attachment points located on the truss framework, each outfitted with power, thermal regulation, and data system interfaces. More attachment points may be added during Station evolution.

Attached payloads which require orientation to specific targets will be accommodated by the payload positioning system (PPS), which will provide a certain degree of positioning accuracy. Payloads which require extreme pointing resolution (on the order of a few arc seconds) will be required to provide their own pointing systems.

An attitude determination system (ADS) will provide attitude knowledge to payloads which require it.



Some examples of "attached payloads" — unpressurized payloads that will be mounted on the Space Station's outside structure.

Pressurized modules

The four pressurized modules on the Station provide a large amount of space for payloads and the crew. Each of these modules is included in the Phase I configuration. The U.S.-built habitation and laboratory modules, however, will be fully outfitted and operational before the launch of the international modules.

The European Space Agency and Japan will provide additional modules. All modules will be pressurized to 14.7 psi with air consisting of 80 percent nitrogen and 20 percent oxygen, approximating normal Earth atmospheric conditions at sea level. All modules are outfitted for power, heat rejection, environmental control and life support, data handling, and long duration crew support.

The U.S.-provided modules will each have space for 44 double-wide equipment racks. The Columbus module will have space for 40 double-wide racks, the Japanese Experiment Module will have space for 24 double-wide racks. Some rack space will be used for storage, permanent equipment, and Station systems. The four modules and resource nodes will provide a combined total of approximately 31,000 cubic feet of pressurized volume.

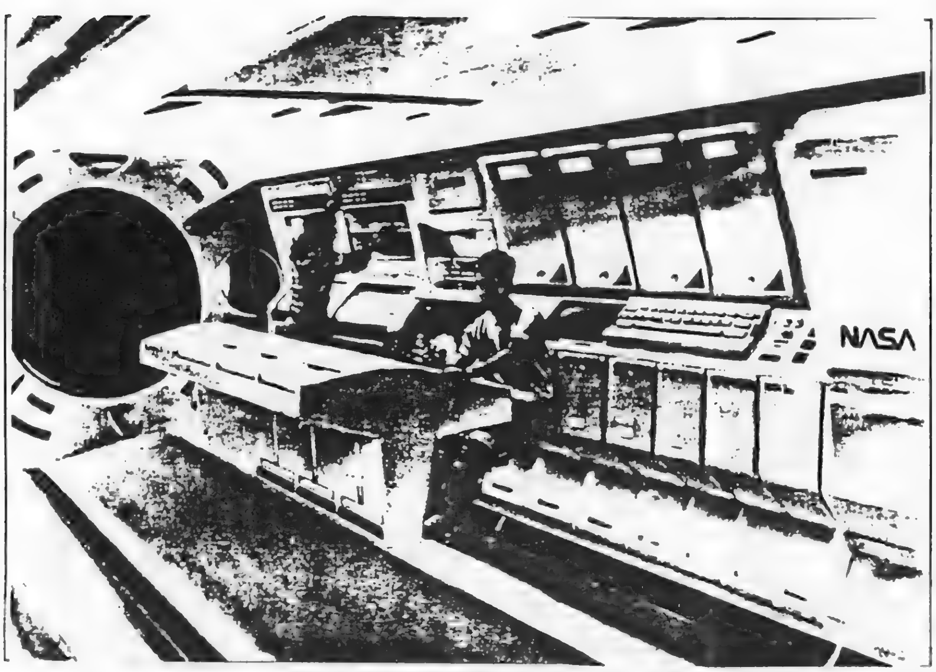
Forty-five dobule racks will be available to U.S.-sponsored users. This will include 29 in the U.S. laboratory module (about 20 will be available for user-provided experiments and support equipment, the rest will contain Station-provided lab support equipment such as glove boxes, incubator, freezer, cameras, etc.) About 10 racks will be available to U.S. users in the Columbus module, about six in JEM.

The placement of the modules is designed to allow the crew to leave any particular module quickly during an emergency to a safe haven, which provides temporary shelter and supplies for crew protection during emergencies. Modules can be sealed from one another to keep fires or dangerous gasses from spreading throughout the Station.

U.S. laboratory

The U.S.-provided laboratory module is designed to accommodate projects that are most sensitive to acceleration – that is, those which need stable microgravity levels. Such projects include materials research and development, and research in basic biology, physics, and chemistry. These projects tend to be of long duration and benefit greatly by the presence of a crew.

The extremely low acceleration levels required in the laboratory module (approximately 10^{-5}g for limited periods of time) will be provided by maintaining the Station's center of gravity in the lab module for the majority of the time. The lab module may also have special provisions for vibration isolation.



Artist's conception of life inside the Habitation module.

Habitation

The habitation module is outfitted to be a pressurized accom-

modation area for both resting and active crewmembers. Habitation outfitting involves the provision and resupply of consumables such as food and toilet supplies. The habitation module will include facilities for health services, recreation, waste disposal and other essential services to support the crew.

Columbus laboratory

The Columbus laboratory module, provided by ESA, is a multipurpose laboratory module for international utilization. It is designed primarily for research in the fields of fluid physics, life sciences, and materials processing.

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Still Needed

The Columbus laboratory module, supplied by the European Space Agency, is designed to accommodate a wide range of scientific investigations.

Japanese Experiment Module

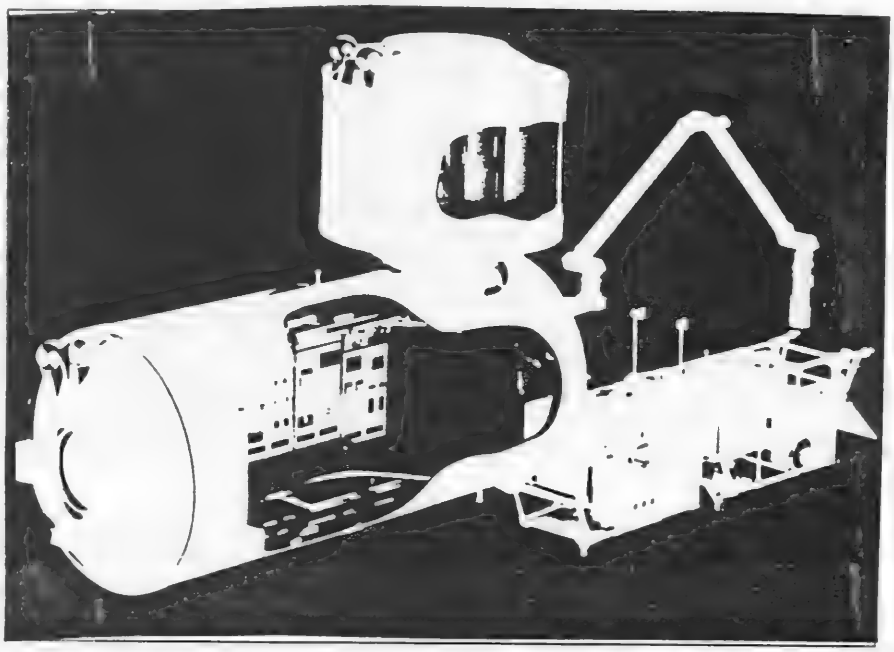
The Japanese Experiment Module (JEM) is equipped to accommodate general scientific and technology development research activities, including microgravity research. The module also contains a multipurpose workstation, which may include controls for attached payloads and servicing. In addition, it includes an exposed (unpressurized) area for the attachment of external payloads and a remote manipulator arm with control center.

Logistic Elements

The logistics elements consist of four types of carriers to transport cargo to the Station. The four logistics elements are the pressurized module, the unpressurized cargo pallet, the propellant pallet, and the fluids pallet. The logistics elements provide for the ground-to-orbit, on-orbit supply and storage, and orbit-to-ground logistics requirements for the Space Station, including the supply of consumables and the return of finished products from payloads.

Logistics elements are carried to the Station in the Shuttle's cargo bay. Various combinations of elements may be used in each resupply flight. Upon reaching the Station, the logistics elements may be exchanged for elements brought to the Station on previous flights. Waste materials generated at the Station are returned to the ground via the logistics modules.

The experiment logistics module (ELM), supplied by Japan, is a pres-



The Japanese Experiment Module (JEM) includes an external "back porch" to accommodate unpressurized payloads. The servicing arm is conrtolled from the experiment logistics element on top of the module.

surized logistic module which will be used to store and resupply experimental specimens, gases and consumable goods, and will be used to transport materials between JEM and Earth.

Resource Nodes

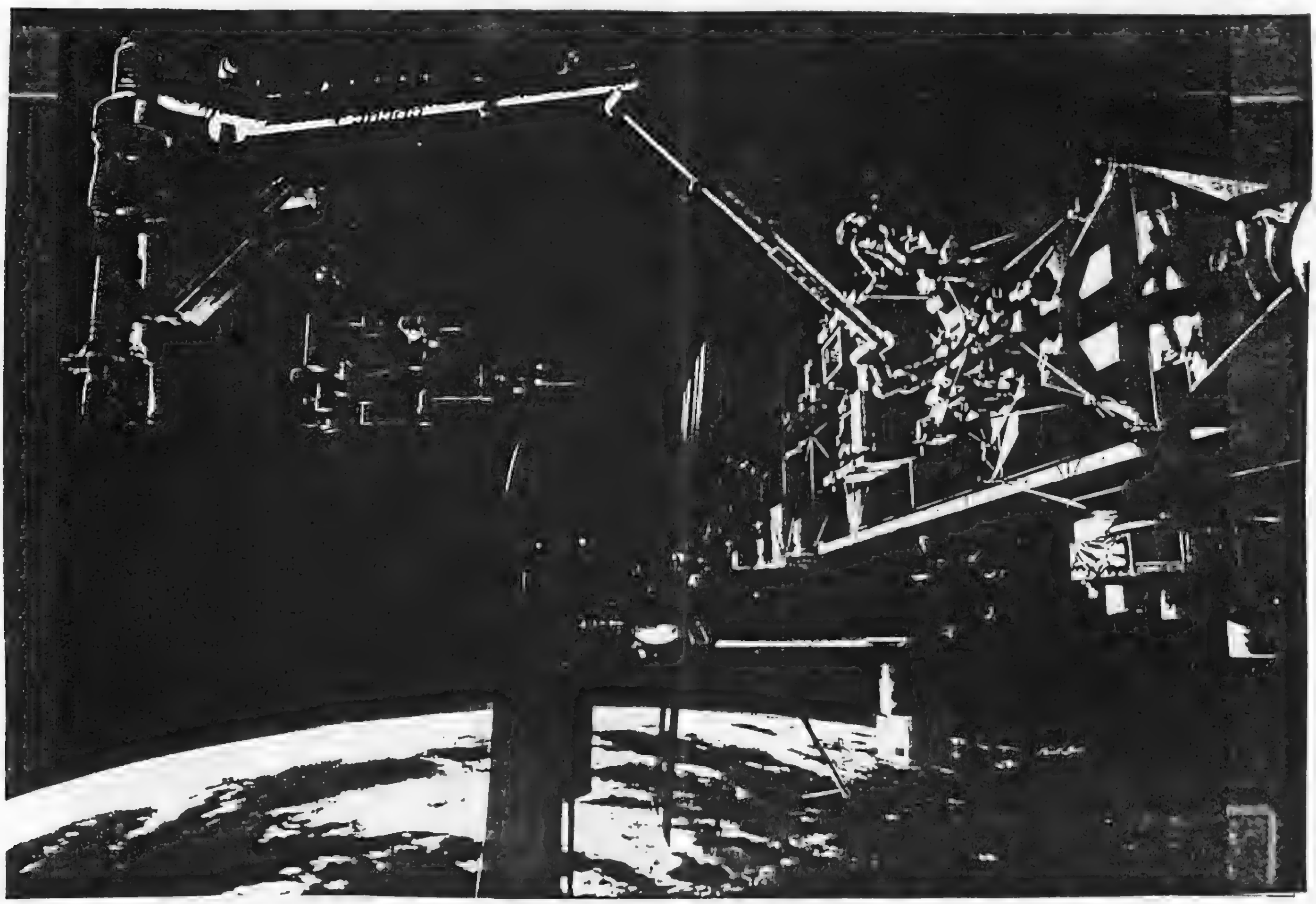
The resource nodes are pressurized, environmentally controlled elements that will link the main modules together. They are designed to accommodate passage among the modules, provide a limited amount of storage area, and house various types of control equipment.

Servicing facilities

A primary function enabled by the presence of the crew is payload and spacecraft servicing. The Space Station includes several facilities and systems to perform servicing.

Mobile Servicing System

The mobile servicing system (MSS), provided by Canada, plays the predominant role in satisfying the functions of external attached payload servicing, Space Station assembly and external maintenance, transportation for deployment and retrieval activities, and extravehicular activity (EVA) support. The MSS is comprised of a base structure with accommodations for payloads, orbital re-



The Mobile Servicing System will be able to move along the Station's framework to provide servicing to payloads without moving them. The flight telerobotic servicer (FTS) or other smart front end may be transported on the MSS's arm to perform the servicing, as shown here.

placement units (ORUs), utilities and thermal control. Included with this structure is the Space Station remote manipulator system or "arm", as well as special purpose dexterous manipulators and servicing tools. The MSS also provides for external and internal control stations for crew operation.

As an adjunct to the MSS, Canada is providing the MSS maintenance depot (MMD). The MMD is the location for MSS spare parts storage, MSS self repair, and maintenance of major Space Station and attached payloads. Initial construction of the MSS takes place during Phase I. With its completion and the addition of the U.S. servicing facility during Phase II, the Station will be fully equipped to service other spacecraft.

U.S. servicing facility

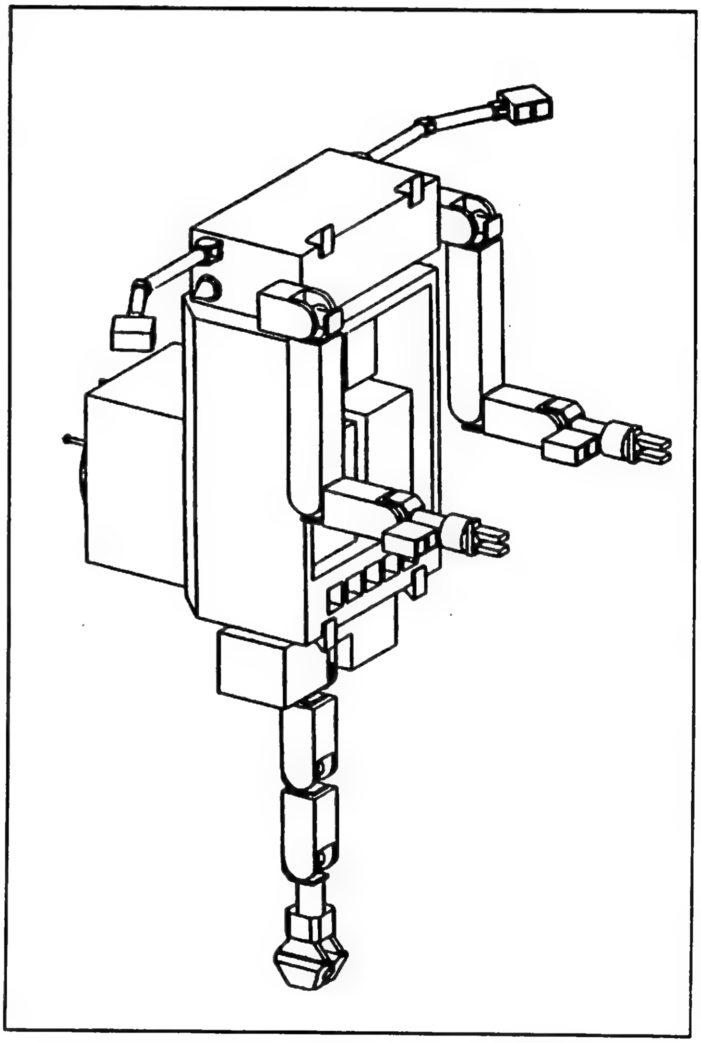
As a part of Phase II evolution, a U.S.-provided servicing facility bay will be positioned on the truss framework to allow protected access to payloads and free-flying vehicles for servicing. The facility contains an in-bay manipulator system that is teleoperated from a control station. The control station operator will be able to grasp a payload, draw it into the servicing facility, and position it for refueling, maintenance, or repair by spacesuited crew members.

The servicing facility provides an integrated servicing and refueling capability. It includes necessary hardware and distributed systems to berth, store, assemble, and repair spacecraft; refuel gases and fluids; and refurbish and check out free-flyers and attached payloads brought to the servicing facility. The servicing facility enables the following kinds of activities:

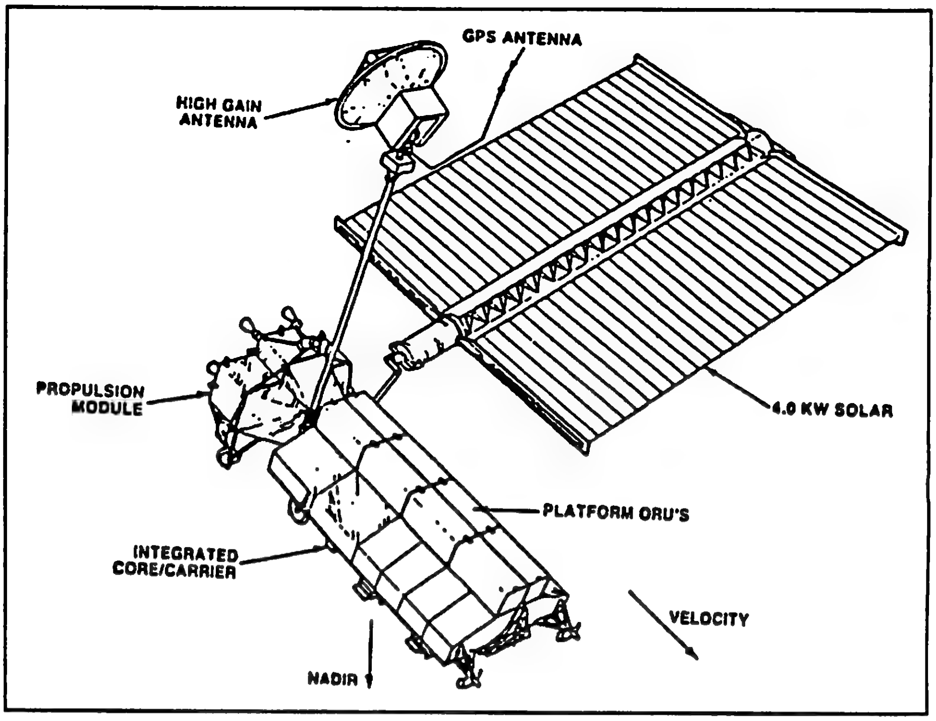
- Replacement or repair of scientific instruments
- Replenishment of consumables, including fuel
- Replacement of limited lifetime subsystems and components
- Replacement or repair of failed modules, subsystems, and parts
- Assembly of free-flyers, instruments, and attached payloads
- Replacement of spacecraft or instrument subsystems to improve performance with new technology
- Storage of attached payloads, orbital replacement units (ORUs), instruments, and tools
- Test and verification of hardware following servicing
- On-orbit accommodation of the OMV between sorties
- Retrieval and redeployment

Flight Telerobotic Servicer

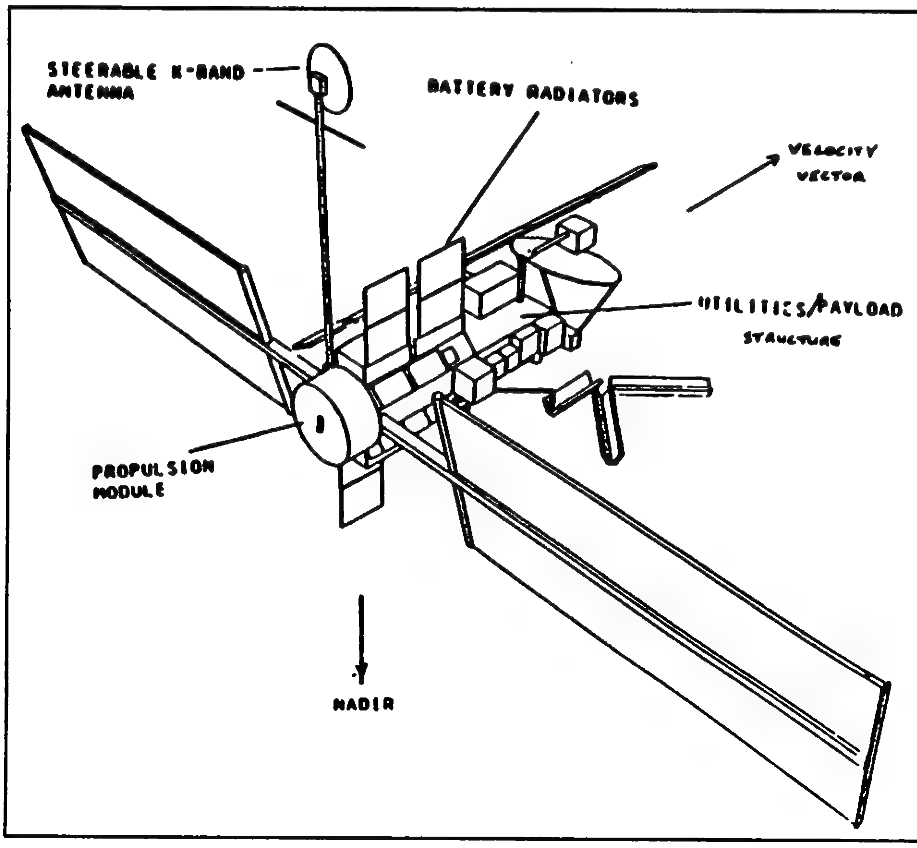
The flight telerobotic servicer (FTS) is a multipurpose tool for the performance of dexterous manipulations in support of Space Station assembly and maintenance, servicing of attached payloads both *in situ* on the Station and in the servicing bay, and – when working from the OMV or the Shuttle – *in situ* servicing of free-flyers and platforms. The FTS can function by teleoperation or in a supervised autonomy mode from a workstation in the Shuttle or Space Station. The use of the FTS will help reduce the EVA workload of astronauts.



The Flight Telerobotic Servicer will be controlled from the Station and will be able to perform manipulations and servicing functions. It will enhance some EVA functions and perhaps reduce the need for EVA.



The U.S. Polar-orbiting Platform will support a wide range of Earth viewing payloads.



The ESA-provided Columbus polar-orbiting Platform.

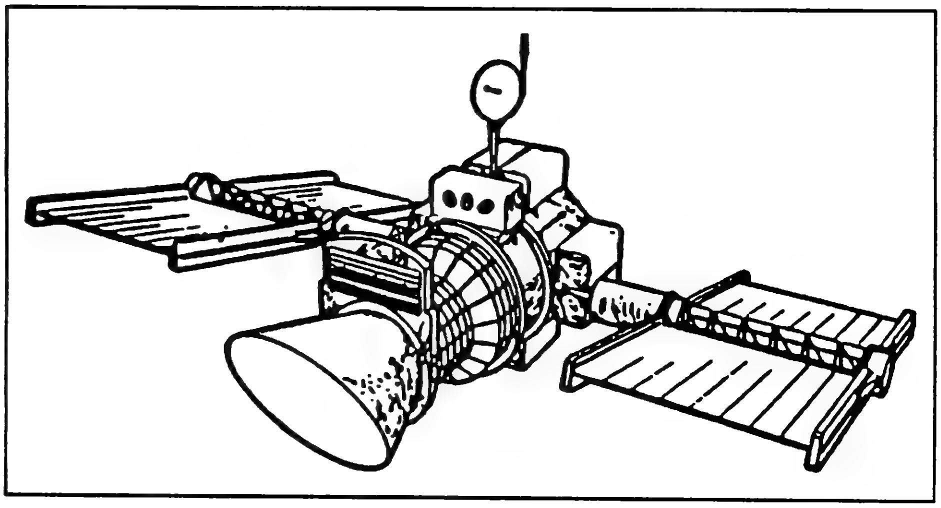
Platforms

In addition to the core Space Station, the Space Station Program design offers unmanned "platforms" that provide accommodations and resources separate from the manned Station base. A platform is a serviceable, orbiting, multi-use structure capable of supplying resources and utilities to changeable payloads, and is dependent upon the Space Station Program for its long term operation. Platforms are not a new idea – they have been a part of most space station concepts since the 1920s.

The Space Station Platforms provide facilities for users to conduct long term, autonomous, unmanned missions and investigations. Accommodations will be made for dedicated or combined missions in the fields of astrophysics, solar exploration, Earth observations, and materials processing. Each Platform is powered by its own onboard photovoltaic electric generators.

Polar

Two polar-orbiting Platforms are included in the Phase I Station configuration. One is being developed by the U.S., the other by ESA. The polar-orbiting Platforms are designed to accommodate payloads designed primarily for Earth observations, which require a sun-synchronous type of orbit.



A co-orbiting Platform will be launched by the U.S. as part of the enhanced capability phase of the Space Station Program. The co-orbiting Platform will be servicable from the Station base, allowing for easy maintenance and instrument changeout.

The elements of the manned base are launched into a low inclination orbit in order to maximize the Shuttle's payload-carrying capacity. However, the ability to view a major portion of the Earth is sacrificed by doing this because a spacecraft in low inclination orbit passes over only the portion of the Earth contained in a relatively narrow band of latitudes. The polar Platforms will orbit in a much higher, near-polar inclination, which will enable the viewing of every point on Earth. Due to its higher orbital inclination, the polar-orbiting Platform will not be serviced from the Station base, but by the Shuttle or a robotic vehicle launched by an ELV.

Co-orbiting

A co-orbiting Platform, developed and operated by the U.S., will be added during Phase II. The co-orbiting Platform is designed to accommodate a wide range of space science, materials processing, and other payloads. The astronomy and astrophysics communities are currently considered as the primary users of the co-orbiting Platform.

The co-orbiting Platform will be in approximately the same orbit as the manned base, but at a slightly higher altitude. It will be accessible from the Space Station base via the orbital maneuvering vehicle for payload changeout and servicing.

Station subsystems and functions

The resources needed by users will be made available by accessing the various Station subsystems. Each subsystem has its own set of attributable functions which may or may not be required by each individual payload. The resources and services described in this section are the result of extensive system and subsystem analyses as well as numerous investigations into the kinds of experiments and work assignments that users have proposed. The result is a generalized set of capabilities that can accommodate the requirements of science, technology and commercial users.

Space Station Subsystems

1. Environmental control and life support system (ECLSS)
2. Propulsion system
3. Thermal control system
4. Fluid management system (FMS)
5. Communications and tracking system
6. Guidance, navigation, and control system (GN&C)
7. Data management system (DMS)
8. Power system

Environmental Control and Life Support

The environmental control and life support system (ECLSS) provides temperature and humidity control, atmospheric supply and revitalization, fire detection and suppression, water recovery and management, waste management, and EVA support.

Propulsion

The Station's propulsion system compensates for drag by the upper atmosphere to keep the Station at the desired altitude and attitude. Fuel for propulsion will be brought to the Station by the Shuttle, but assessments are being made to determine the feasibility of using hydrogen and oxygen from waste water for propulsion.

While orbital decay can be compensated for by the continuous firing of microthrusters, drag will instead be corrected by the firing of much larger thrusters every 90 days or so. This allows the Station to drop in altitude periodically to coincide with resupply trips by the Shuttle. After rendezvous and resupply, the Station will fire onboard thrusters to regain operational altitude.

Thermal Control System

The thermal control system (TCS) will maintain the temperature of the structure and components of the Station within specified limits. In addition to passive thermal control measures such as insulation, surface coatings and isolators, waste heat acquisition and transport will be provided by each module to collect and transport waste heat generated by the Station, crew, and payloads. Waste heat will be transported to cooling radiators mounted on the Station truss via an ammonia loop.

Fluid Management System

The fluid management system (FMS) will provide facilities for the storage and transfer of fluids, primarily liquid nitrogen, water, and waste.

Guidance, Navigation and Control

The guidance, navigation and control (GN&C) system controls guidance, navigation, altitude, attitude, and proximity operations and traffic during all mission operations. The system establishes Station position with respect to stars or the Earth, then maintains that position according to defined requirements. The GN&C system also points the power system and thermal radiators to provide the most efficient operation.

The GN&C system uses well established technology which will allow users to predict the exact orbit speed, attitude, and altitude at all times, providing users with a stable base from which they can fine point their instruments.

Power

The Phase I Space Station provides 75 kw of electrical power to operate the Station and payloads. Approximately 45 kw of the 75 kw generated will be available to user payloads. Several internal racks will be outfitted for about 15 kw of maximum power; most racks will be allotted a maximum of 3 kw. A maximum of about 10 kw will be deliverable to external attached payloads.

During the time the Station is hidden from the sun by Earth's shadow, batteries will be used to provide electrical power, so electrical power levels will be constant during all stages of orbit. Platforms will operate with their own power systems.

Station power will initially be generated by photovoltaic cells. In the future, solar dynamic heat engines will be added to supply additional power.

Crew services

Intravehicular activity

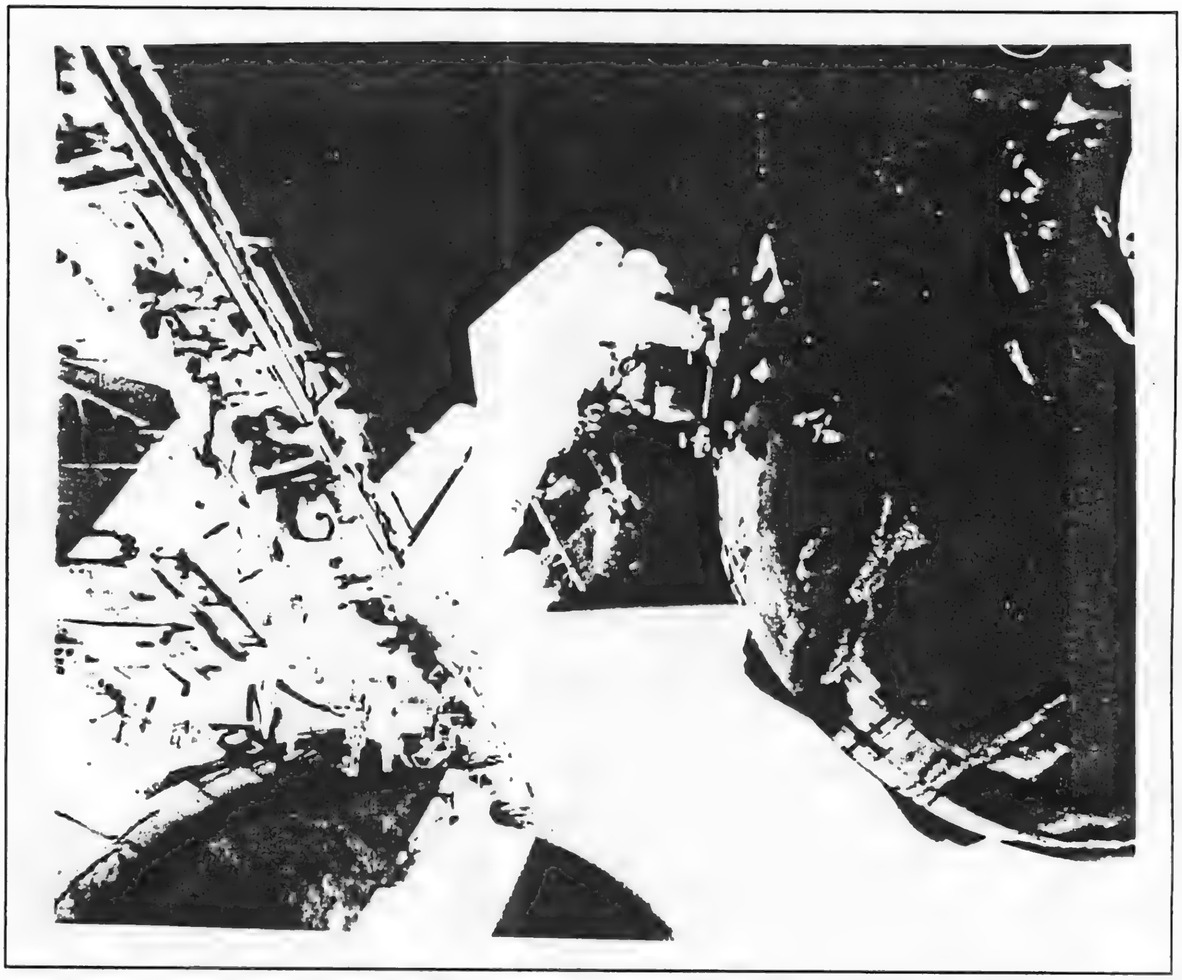
Intravehicular activities (IVA) are tasks performed by crewmembers inside the pressurized modules of the Space Station. Standardized workstations are available in all locations where work is to be done. Each workstation has access to the communications and data management systems.

A typical crew compliment consists of eight persons, including two Station operators, one designated as Station commander, the other deputy Station commander. Of the remaining six, at least four will be Station scientists (career Station science generalists trained to install, operate and observe user payloads and experiments) and the remainder will be payload scientists (non-career crewpersons who function as science specialists for designated payload applications and types). The crew will work two four-person shifts.

Extravehicular activity

Extravehicular activity (EVA) is any operation performed by spacesuited crewmembers outside the Space Station. A significant amount of EVA will be required to assemble the Station. After regular operations have commenced, EVA will be used to service external payloads and to maintain and enhance the Station. Some EVA servicing will be assisted by, or replaced by, robots commanded from the Space Station.

During initial Station construction, astronauts will be protected by the same space suits now used on the Space Shuttle. Since the pressure of the Shuttle suit is



Astronaut William F. Fisher, anchored to a foot restraint on the end of the Shuttle's "arm", works on the Syncom IV-3 satellite. Such Shuttle missions proved the utility of manned presence to perform repair tasks in space.

much lower than the pressure in the Shuttle or Station, the crewmember must breathe pure oxygen (known as prebreathing) for several hours before leaving the Station in order to avoid decompression sickness.

To avoid delays of prebreathing, a new Space Station spacesuit is under development. The new suit will be a hard, high pressure suit that maintains an internal pressure of at least 8.4 psi, which allows EVA with little or no prebreathing. The shortened preparation time of a hard suit significantly adds to EVA productivity by lengthening the time that the astronaut can be outside the Station. Also, the new suit will require significantly less on-ground servicing than the current Shuttle suit.

To enhance the capabilities of astronauts performing EVA, the astronauts will use the manned maneuvering unit (MMU), allowing manned free-flying operations around the Station out to at least a 300 meter distance. MMUs were used on the Shuttle and have proven to be effective in support of EVA.

EVA capabilities

The following tasks have been identified as representative of EVA capabilities:

- Inspection, photography and manual override of payload systems and mechanisms

- Installation, removal, and transfer of film cassettes, material samples, and instrumentation
- Operation of equipment, including standard or special tools, cameras, and cleaning devices
- Cleaning of optical surfaces
- Connection, disconnection, and stowage of fluid and electrical umbilicals
- Replacement and inspection of modular equipment and instrumentation on a payload
- Remedial repair and repositioning of antennas and solar arrays
- Activating, deactivating, or conducting extravehicular experiments
- Mechanical extension, retraction, or jettison of experiment booms
- Removal or installation of protective covers or launch tiedowns
- Transfer of cargo
- Large structure assembly or construction
- On-orbit satellite servicing

Space Station Information System

The goal of the Space Station Information System (SSIS) is to provide information and data handling for the users (onboard crew and customers) of the Space Station complex.

NASA's tracking and data relay satellite system (TDRSS) is the primary space-to-ground communications resource used by the SSIS. (TDRSS is explained in more detail later in this document.) Alternative tracking and data acquisition facilities will be integrated as they evolve. The European and Japanese tracking and data relay satellites will be able to provide alternative and additional communications resources for the SSIS.

The SSIS is comprised of data processing and communications hardware and software on the Space Station and Platforms, relay satellites in space, receiving stations, data handling centers, and control and processing centers on the ground and the interconnections between them. SSIS is functionally organized into two elements: the data management system (DMS) and the communications and tracking (C&T) system.

Telescience

Science operations will be conducted within the Space Station Program according to the transaction management approach to payload control and resource management. This concept is based on reactive control rather than command checking and depends on preplanned envelopes of resources needed for a particular experiment. This approach will provide the remote interactive operations of flight instruments from distributed user facilities.

(More TBD)

Data Management System

The data management system (DMS) controls the storage and transmission of downlink data, video, and voice through TDRSS. The architecture of the DMS, which is the onboard portion of the SSIS, consists of two local area networks, network interface units, mass storage devices, and a family of standard data processors. One of the networks will carry Station engineering and housekeeping data, the other will carry low rate (about 10 mbps or less) payload commands and data to and from user payloads. High rate payloads will be serviced by dedicated buses connecting them to the communications and tracking system. The maximum total data rate from the manned base will be about 300 mbps; attached payload points and internal racks will be limited to about 50 mbps

each.

The DMS provides data storage, processing and handling, and onboard networking services to accommodate most user requirements. It employs common hardware, software, and standard interfaces and formats when cost effective and when other objectives are not compromised.

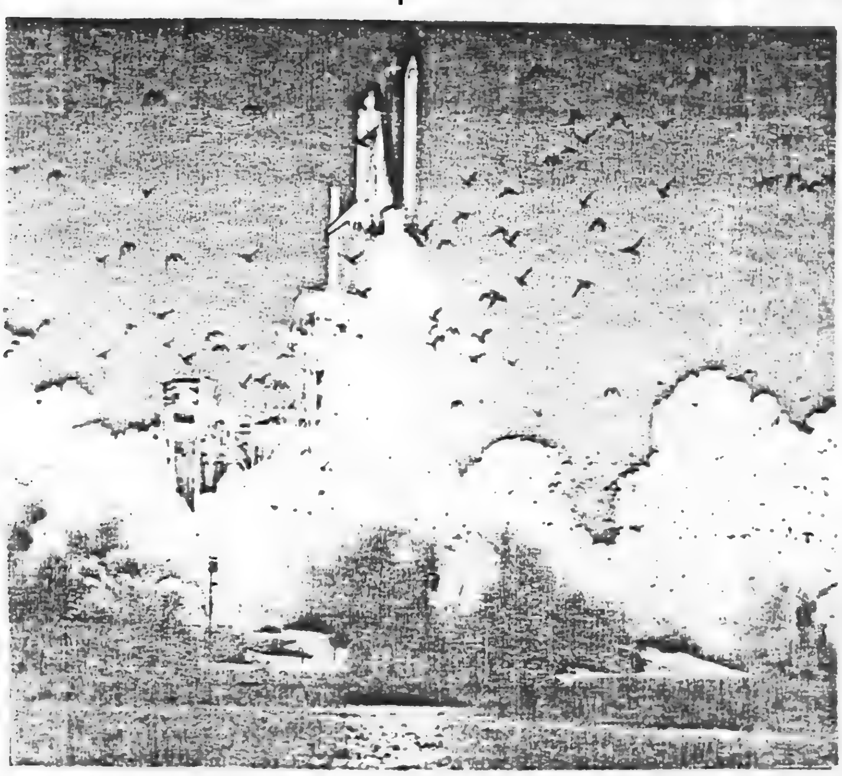
The DMS can store sufficient engineering and payload data to provide adequate buffering during communications outages. Outages will occur when the Station passes through the approximately 15 minute-per-orbit zone of exclusion and when the Station antennas are turned to the next tracking and data relay satellite (TDRS). User data will be stored only as long as necessary for the user to verify acceptable data quality, subject to a specific time limit to be established by the Program. Acceptance of the delivered data by the investigator releases the SSIS from any further data storage obligation.

Communications and Tracking

The communications and tracking (C&T) system provides for the transmission, reception, distribution, data storage, signal processing, and controlling of audio, telemetry, commands, data, video, text and graphics, and tracking data for all elements of the Space Station Program. The tracking function monitors the location of the Space Station and other spacecraft in the vicinity of the Station.

Security provisions

The SSIS provides data privacy for users of the Space Station. Privacy consists of file protection, password implementations, and other standard security functions employed in a typical information processing facility. Protection of user voice and video data is also provided. The SSIS allows users to employ additional command and data privacy mechanisms which are compatible with the SSIS command management policy.



The Space Shuttle will be used to carry the Space Station into orbit for assembly, to launch and return payloads, and to ferry crews between the Station and Earth.

Supporting programs

This section describes some NASA programs which will be utilized to support or enhance the capabilities of the Space Station Program.

National Space Transportation System

The National Space Transportation System (NSTS) encompasses all hardware systems and support equipment, facilities, and personnel to deliver payloads to Earth orbits and to perform on-orbit operations and experiments. The Shuttle, the principal element of the NSTS, remains the nation's primary launch system for both national security and civil government missions, and it will be utilized by the Space Station Program in several ways:

- Delivery of the various Space Station Elements
- Assembly and checkout of the Space Station systems
- Transportation of crew members
- Transportation of user payloads and

materials to and from the Station
- Periodic logistics flights to the Station to support ongoing operations.

The Shuttle will be the launch and return transportation system for the Program elements and for the U.S. polar-orbiting Platform during Phase I. (An exception is the ESA Platform which may be launched by the Ariane.) Other transportation systems are being considered for use during Phase II.

Tracking and data relay satellite system

The tracking and data relay satellite system (TDRSS) is used for communications between space and Earth. TDRSS, which has been used in the past to support Shuttle missions, is an evolving system of Earth-based receiving stations and geostationary satellites which relay data from space to Earth. As the Space Station orbits the Earth, communications will break when, after leaving the operational area of one TDRSS satellite, the Station's antenna is rotated to acquire a view of the next satellite.

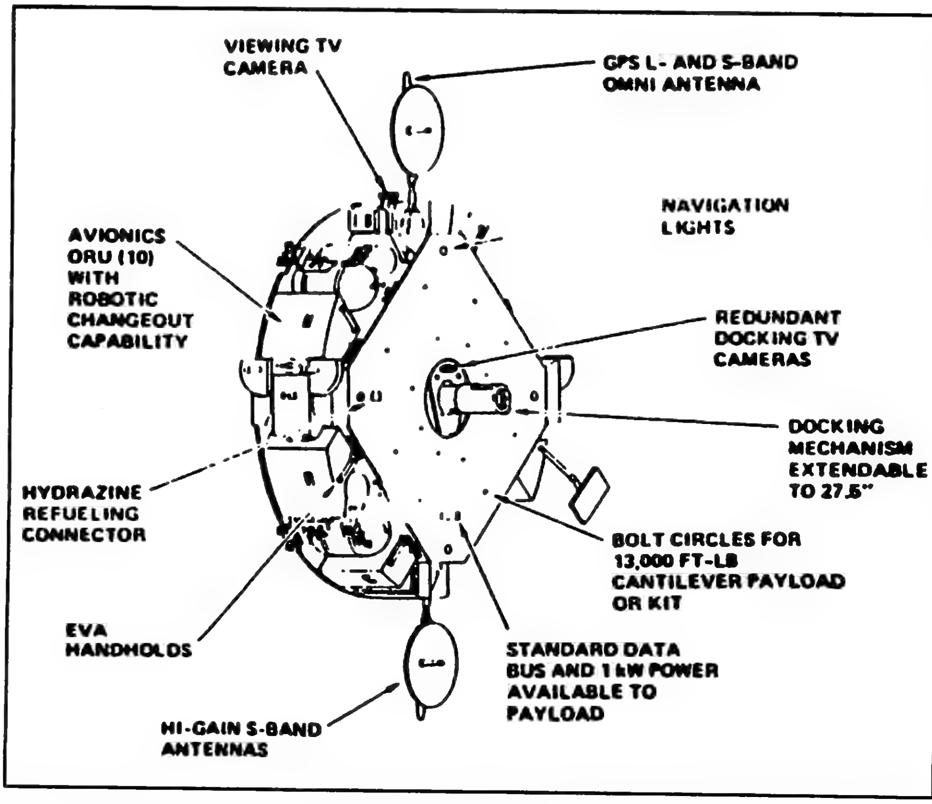
The equivalent of two TDRSS single access links (Ku band plus S band) have been allocated to the Space Station Program, one link for the Space Station base and the other for shared use by the Platforms.

Users may, if desired, supply their own communications equipment as part of their payloads for direct communications to facilities on Earth without going through the TDRSS network. This includes data from the core Station (and its attached payloads), free-flyers, and Platforms.

Orbital Maneuvering Vehicle

The orbital maneuvering vehicle (OMV) is a reusable, remote controlled free-flying vehicle which performs propulsion and retrieval functions for other orbiting spacecraft. It is designed to be operated from either the Station or the Space Shuttle. The OMV is projected as an important element of the Space Transportation System and, although it will not considered to be an element of the Space Station Program until it is based there in the mid 1990s, core Station operations will be dependent on the OMV for a variety of support activities when it starts operating from the Shuttle in the early 1990s.

Multiple propulsion systems and onboard avionics enable the OMV to deliver and retrieve satellites to and from high orbits. Precision maneuvering, including docking with an orbiting satellite, is accomplished by manned operation of the OMV control station. Limited resources are available for payloads while attached to the OMV, but more extensive services can be considered on a case-by-case basis. The OMV offers the following capabilities and



Concept of the orbital maneuvering vehicle.

characteristics:

- Transfer of spacecraft to and from the Space Station base for servicing
- Spacecraft delivery, retrieval, reboost, deboost, and viewing
- The utilization of a cold gas reaction control system (RCS) for minimum contamination during final docking maneuvers
- The ability to service satellites at geosynchronous orbit in conjunction with an orbital transfer vehicle (OTV)
- The ability to grow in capability to accommodate various mission kits for special servicing tasks such as refueling or module exchange.

Orbital Transfer Vehicle

The orbital transfer vehicle (OTV) is a larger, more powerful spacecraft than the OMV, and will be capable of hauling large payloads up to high altitudes. The OTV will enable advanced space endeavors such as geosynchronous delivery of large platforms and missions to the moon and the planets. It can also retrieve satellites from higher orbits. A failed satellite, for example, could be brought down to the Station for repair or refueling. The OTV has not yet been scheduled for production.

III. SPACE STATION USERS

User classes and disciplines

A "Space Station User" is any individual, group or agency responsible for the development and/or operation of a payload or mission utilizing a component of the Space Station Program. User classes expected to participate in the Space Station Program include science and applications research, technology development, cooperative commercial, and reimbursable users. Cooperative commercial users are those performing research and development activities under cooperative agreements with NASA. Reimbursable users are those who will pay their own way on the Station, and primarily include non-NASA government agencies, such as the National Oceanic and Atmospheric Administration, and commercial firms. The terms "investigator" and "user" are used interchangeably in this document.

Users will conduct experiments in a broad range of fields. Research disciplines which are considered particularly appropriate for Space Station payloads are listed below.

Science

Astronomy and astrophysics

The Space Station will accelerate the pace of research in astronomy and astrophysics, disciplines that have benefitted greatly from access to space in the past. While the new generation of space observatories, such as the Hubble Space Telescope, do not require the Station for regular operations, they will be able to use Station resources for servicing, regular maintenance, repair, and for instru-

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still needed

The Space Telescope may be one of a class of non-Space Station payloads that make use of the Station's servicing capabilities to extend its life in orbit.

ment replacement, updating and reconfiguration. This will contribute to an increased lifespan for these instruments.

The Program also provides co-orbiting Platforms and attachment points on the Station's truss structure for payloads, such as instruments to enhance gamma-ray, ultraviolet, optical, infrared, radio and X-ray astronomy. The enhanced capabilities phase could expand Station resources to accommodate the assembly, operation and deployment of new large scale science facilities to support on-orbit research or exploratory missions of the solar system.

Solar system exploration

Research into the evolution and composition of our solar system can be enhanced by long duration experiments that collect data and samples from the Space Station. Studies of meteorites and interplanetary dust particles collected in the upper atmosphere have contributed fundamental information to the planetary sciences, and may provide evidence of extraterrestrial life.

For future missions to the planets and other bodies, the Space Station may accommodate the assembly of spacecraft that are larger and more complex than those built on the ground, permitting new laboratory studies of extraterrestrial materials.

Solar-terrestrial processes

The sun-Earth system can be studied from the Space Station complex by combining remote sensing techniques, active experimentation, and co-orbital free-flyers. The solar-terrestrial processes discipline encompasses the study of the entire sun-Earth system, including the detailed study of solar processes, the relationship between changes in the sun and resulting changes in the Earth's magnetosphere and atmosphere, and the detailed physics of the Earth's magnetosphere-ionosphere-atmosphere system. The study of the sun, magnetosphere, and atmosphere will require measurements from the Station's manned core as well as from the Platforms.

Earth observations

The field of Earth observations consists of activities related to the study of the structure and resources of the Earth and its environment. Since Earth observing activities demand high pointing accuracy and low disturbance, they are best performed on unmanned platforms. Most Earth observing instruments will be placed on the polar Platforms because the polar orbits provide global coverage. However, opportunities also exist for observations from the Space Station Elements in low inclination orbits.

Life sciences

A primary goal of life sciences research on the Space Station will be to understand the effects of microgravity on living organisms. This interest is focused in three directions: understanding subtle physiological processes which are masked by gravity; research into phenomena such as space adaptation syndrome and osteoporosis, which may provide insight into similar illnesses on Earth; and research into the long term effects of weightlessness – an important topic considering the long duration of crew shifts on the Space Station base.

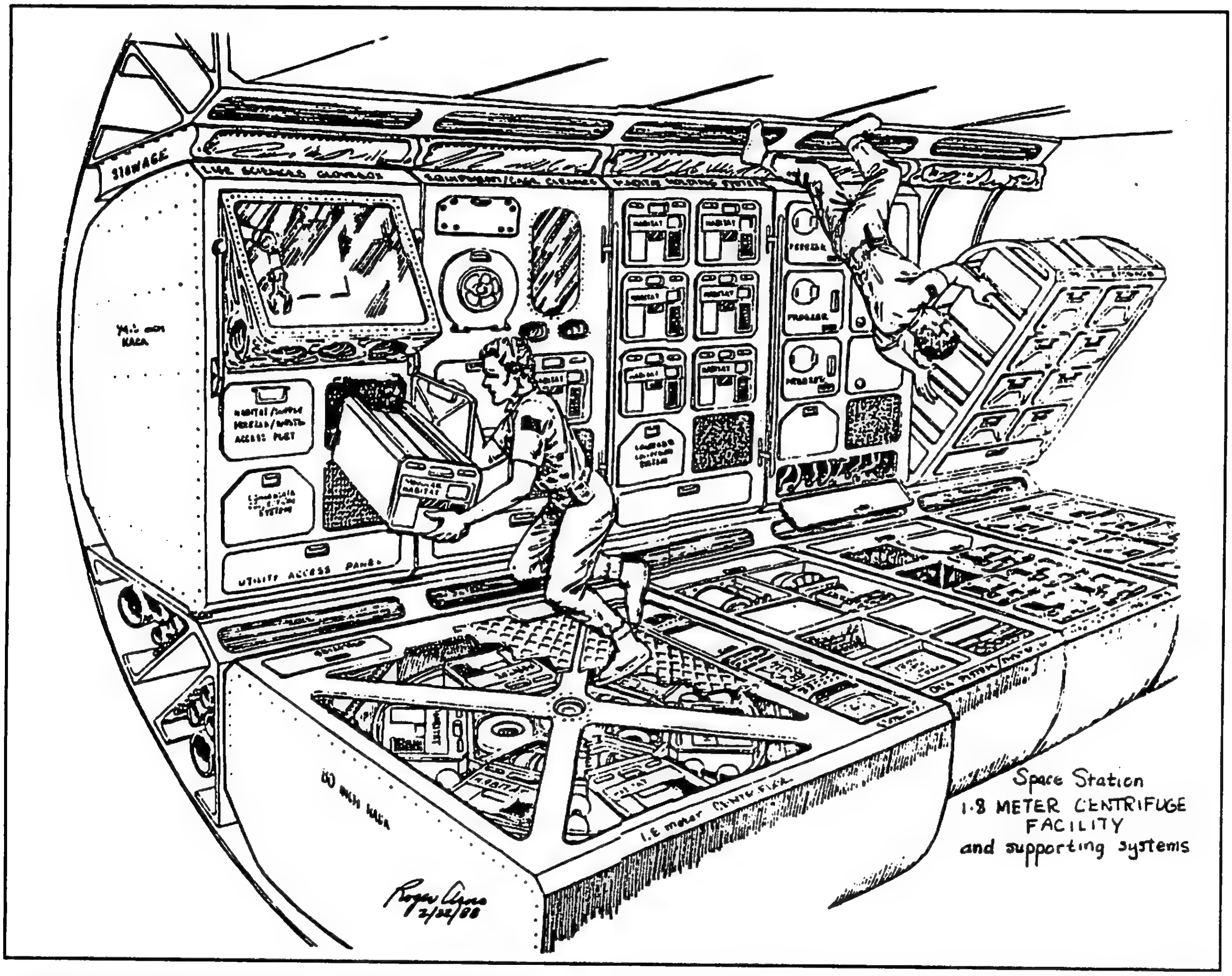
Although considerable knowledge about the adaptation of the human body to a weightless environment has been gained from Skylab and some recent Shuttle experiments, much still needs to be learned about the mechanisms and limits of human adaptation to prolonged spaceflights. Without this knowledge, it is impossible to gauge the possible physiological and psychological consequences of prolonged exposure to this environment. The development of countermeasures

for the untoward effects of microgravity is a major research goal. Currently, life science research activities are of primary interest to NASA, the Partner governments, and to the academic community, though private sector interest may grow as the capabilities of the manned base become more apparent.

Life sciences research will also involve space medicine studies, gravitational biology studies of how gravity has shaped and affected life on Earth, and remote observation of the ecology of the Earth. As in the past, much of what will be learned in space will have direct impact on improving the quality of life on Earth.

Materials science

Materials science is one of the most promising fields planned for the Space



Gravitational force can be simulated in the microgravity environment of the Space Station by the centrifugal force created by a centrifuge. The centrifuge can be used to hold biological specimens at normal Earth gravity levels to serve as experiment controls, or they may be spun at rates that maintain fractional levels of artificial gravity to determine "thresholds" for various effects of weightlessness.

This artist's conception shows the centrifuge in the "floor". The astronaut in the foreground is loading a cage into a glovebox so tissue samples can be taken. Freezers, computer workstations and other life science support equipment are also depicted.

Station's facilities, and will involve science, technology and commercial users. Materials science is aimed at developing a better understanding of how microgravity affects materials and processes. Results from this research will lead to improvements in Earth- and space-based processing techniques. Pilot production processes will also be developed.

Major areas of materials science research include biological, organic and pharmaceutical substances; inorganic crystals; advanced glasses and ceramics; metals and alloys; combustion technologies; and polymer chemistry. Microgravity science users often have significant power requirements and need access to a highly stable microgravity environment.

Technology development

The availability of the Space Station complex as a facility for conducting in-space research, technology, and engineering experiments will contribute to the success of manned spaceflight by permitting more sophisticated and longer duration activities. Benefits from space-based technology experiments will include the reduction of costly ground-based simulations, improvement of design margins, improved technology transfer, and the reduction of the risk factor in space development and operation. As in the past, many of these technologies will be transferred to other government agencies and the private sector to improve technology and the quality of life on Earth in a surprising number of ways.

As a means of understanding the scope of in-space experiments, the NASA Office of Aeronautics and Space Technology has selected seven themes into which any given space technology experiment can be classified. These categories are described below.

Space structures (dynamics and control)

As space systems of the future become increasingly large and flexible, the issue of interaction of controls and structures becomes extremely important. Because of their size and the inability of large space structures to be self supporting in a one-g environment, on-orbit testing and experiments are needed. New control devices and techniques must be tested, and basic observations must be collected. The general goals of this discipline are to obtain data to validate Station characteristics, to provide a technology base for large space structure assembly, to investigate the many aspects of flexible structures control, and to provide a basis to update ground-based models and simulations.

Fluid management

In-space experiments will be needed not only to characterize the fundamental nature of fluids, but also to develop the means to handle fluids in space. This is applicable to space-based materials processing, life support, propulsion system servicing, thermal management, and advanced sensor systems. A vital element of future materials science research will be the development of processing techniques designed for a microgravity environment to mix new alloys, pharmaceuticals, and other ultrapure substances. Such techniques will ultimately lead to "containerless processing". Several Shuttle experiments have attested to the success of developing these techniques, but the long duration enabled by the Space Station makes it an ideal environment for further experiments. Another early emphasis in this theme will be to provide research data for the long term storage and transfer of cryogenic fluids in space.

Space environmental effects

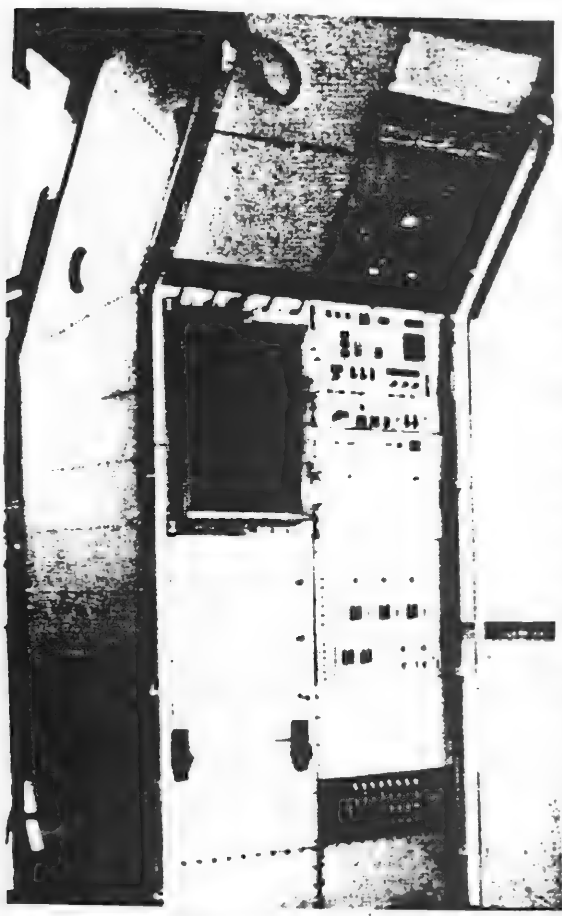
This theme is primarily concerned with the effects upon humans and artificial objects in orbit. At issue is not only natural phenomena, such as trapped radia-

tion or spacecraft charging, but also contamination and manmade orbital debris. In-space experiments can be used to characterize effects of the space environment upon computer systems and their components, materials, power systems, and humans. Research will establish a technology data base for the development of long life materials and coatings, provide a complete characterization of the local Space Station environment, and improve the understanding of in-space effects upon microelectronic and electro-optic data systems.

Energy systems and thermal management

The need to understand the behavior of new energy systems and the management of heat sources has led to space-based experiments and demonstrations. Prime energy and power systems such as solar powered heat engines, nuclear power, and electrodynamic power generation are among those competing techniques which need to be investigated. Many of these concepts are tied to the growth of the Space Station.

The thermal management portion of this theme revolves around the need to manage heat sources. Applications such as sensor technology and propulsion systems will require the manipulation of ultra-cool liquids. Initial emphasis in this theme will be to fully evaluate advanced solar dynamic power systems, subsystems, and components, and to develop a technology base for advanced radiator concepts.



The low gravity levels in space enable the manufacture of liquids and other substances that are impossible to create on Earth. This "drop dynamics madule" flew on the Shuttle, and proved that liquids could be mixed and manipulated without the use of physical containers.

Information systems

Information systems technology involves the areas of sensor systems, computer and data systems, and communications systems. The overall goal is to develop information systems that will provide more efficient and effective transfer of data from sensors to users via intelligent, autonomous systems.

Sensor experiments are intended to enable *in situ* characterization and optimization of sensor system elements, and to develop new remote sensing options. The objectives of data systems experiments are to provide an on-orbit electronics qualification capability, to evolve high speed onboard signal processing technology, and to develop large capacity onboard data storage and retrieval technology. The communications discipline is aimed at enabling new com-

munications options and providing a capability for in-space communications system characterization and optimization. Each of these technologies have direct uses on Earth.

Automation and Robotics

Automation and robotics (A&R) comprise those technologies that will permit automatic control of a variety of functions. Automation refers to the control of physical processes partially or completely independent of human intervention. At the highest level, automation includes the performance of cognitive tasks, such as scheduling, planning, fault diagnosis, and decision making. Robotics is a branch of automation that utilizes technologies and devices that enable the performance of manipulative tasks, such as grasping, positioning, or moving an object.

A&R is of particular importance to the future of space systems, especially its potential to extend man's reach in the environment of space. A&R technologies will be beneficial in such areas as payload engineering, payload operations and control, ground and space communications network management, and satellite and payload servicing. Since human resources in space are limited, the introduction of autonomous systems will relieve the crew from monotonous, routine or dangerous tasks and allow them more time to focus on operations and research activities. Robotic systems can be used to advantage in the assembly of large space structures, servicing, and docking. Advantages accrue not only from potential cost savings in comparison to many hours of expensive extravehicular activities by the crew, but also from the reduced exposure of crewmembers to space, thereby improving safety margins.

Views of Earth from space allow for a unique view of the planetary environment. This high resolution radiometer shows Italy.

In-Space operations

The plan for the permanent presence of humans on an orbiting Space Station requires a re-examination of issues pertaining to space operations. Investigations into new technologies for life support systems, servicing, and tether systems are key areas. Because one of the major features of the Station is to act as a "node" in a larger space operational structure, technologies dealing with servicing of orbital transfer vehicles and satellites must be addressed early.

Commercial

The Space Station will help NASA further the United States' goal of expanding private sector investment and involvement in civil space activities. Commercial users of the Space Station will be private sector companies that wish to perform research, development, or pilot production activities taking ad-

vantage of the characteristics of the space environment. These commercial projects will aim at developing profitable products and services in space for sale to consumers on Earth and for other space activities.

The existence of the Space Station will naturally spark interest in new products and processes, as well as new business opportunities. Commercial entities will generally venture into space if there are substantial benefits such as cost reductions or profit opportunities not available in Earth-based efforts. To protect private sector interests, provisions for onboard handling, support, and restriction of access to proprietary equipment and information will be provided.

Several research disciplines may offer numerous opportunities to the commercial community; these include materials processing, telecommunications, Earth and ocean observations, and industrial services.

Materials processing

Materials processing activities will utilize the Station's long duration microgravity environment to examine the role of gravity on material properties. Results from materials processing research will lead to materials that cannot presently be made on the ground. Commercial activities will most likely focus on high value, low weight materials such as pharmaceuticals, electronic materials, glasses, crystals, metals and alloys.

Telecommunications

The telecommunications industry will benefit from the Space Station through cost savings for communications satellites, and enhanced satellite capabilities or performance. The Space Station will provide commercial opportunities in the communications field as a control center for satellite transmissions, a relay and switching network, and as a base for the assembly and servicing of communications platforms. Commercial firms may also use the Space Station to investigate new technologies, such as multi-beam antennas, satellite relays, and optical communications.

Earth and ocean observations

Earth and ocean observations made from orbit provide vast amounts of information on the Earth's environment and its resources. Commercial opportunities exist in the collection and dissemination of remote sensing data from satellite systems. The Space Station can enhance current satellite technology in ways outlined for the telecommunications industry above. Also, the Space Station can support co-orbiting free-flyers that will continuously collect remotely sensed ocean and land data.

The need for remotely sensed ocean data for weather, oceanographic, and navigation hazards clearly exists in the private sector. Industries such as shipping, fishing, and oil and gas exploration depend on accurate ocean data.

Similarly, there is a need for satellite imagery of Earth, which has proven useful in a wide variety of national and international disciplines. Land remote sensing data is required by agricultural firms, geologists, urban land use planning, and environmentalists.

Industrial services

The Space Station will also generate opportunities for providing utility services to the nation's industries or to other users of the Station. Industrial services will be sought when the Space Station infrastructure is mature enough to support commercial activities in space for extended periods of time. Examples of such services are: power generation, habitation features (such as crew accommodations, recreation facilities, and food preparation), medical care, personnel ser-

(Chart showing various opportunities for Materials Processing – coming)

vices, and rent or sale of standardized modules that may be attached to the Space Station complex or free-flyers.

Program Selection and Sponsorship

Sponsorship options

Sponsorship options for users of the Space Station Program are the same as offered by earlier programs. Each user class is assigned a sponsor Program office within NASA. The Office of Space Science and Application (OSSA) will select science users in traditional discipline areas such as materials processing, life sciences, astrophysics, and environmental observation. Selection of technology development users is the responsibility of the Office of Aeronautics and Space Technology (OAST). Commercial cooperative users are sponsored by the Office of Commercial Programs (OCP). All reimbursable users (both commercial and other government users) will be the responsibility of the Office of Space Station (OSS). The addresses for these offices are listed in Appendix 4. Each NASA office will be responsible for maintaining a selection process that allows them to determine which programs will help them achieve their goals.

User selection

The user selection process is based on the available Space Station resources within each NASA Office. Most of the currently defined user classes, with the exception of commercial users, have peer review systems in place to determine what payloads they will develop and fly. The organization representing each user class selects individual users and determines their resource "envelope", which is the sum total of all resources available for payload operations at a given time interval. Payloads are selected not only for their technical or scientific merit, but also for their ability to function with minimum interference to other payloads and for their compatibility with a specific class of payload.

Science and technology users selection process

The standard selection procedure for science and technology users involves the periodic issuance of announcements of opportunity (AOs), which request the submission of proposals for a specific area of research. AOs are distributed through NASA mailing lists and are published in *Commerce Business Daily.* The AO will specify the range of subjects appropriate for proposals, the proposal format required, where to send proposals, the deadlines involved, and the selection schedule. Some AOs have a specific deadline, others are open ended and are reviewed periodically.

Users may also submit an unsolicited proposal, which is any proposal not prepared as a direct result of a formal NASA solicitation. NASA issues notices from time to time that describe ongoing programs and areas of activity appropriate for unsolicited proposal submission. Unsolicited proposals need not be submitted in a particular format. However, all proposals must contain sufficient scientific, technical, and budgetary information to allow a thorough and equitable review. NASA is under no obligation to respond to unsolicited proposals and may consider them only as correspondence.

All solicited and unsolicited proposals are formally reviewed by an outside panel of peers for scientific merit, programmatic relevance, feasibility, and resource requirements. Following an internal review cycle, the Associate Administrator of the sponsoring office will select investigations for definition studies. This process of review and selection requires approximately one year to complete.

Commercial and reimbursable users selection process

Commercial and reimbursable users are not solicited by AOs. These users may learn of Space Station Program opportunities for research and development through the Office of Commercial Programs' outreach activities, which include conferences, target visits, advertising, and articles in trade journals or the general press. Potential users may also contact the Office of Space Station on their own initiative, and will be directed to an appropriate sponsor for further information.

Commercial and reimbursable agreements

In the Shuttle era, several types of agreements were used between NASA and commercial or reimbursable customers. These agreements, or new agreements based on these, will be used by the Space Station Program.

Space Shuttle Launch and Associated Services Agreement. This agreement provides launch and associated services to commercial and foreign customers on a reimbursable basis. Launches are provided at a fixed price plus escalation from a base pricing year for standard services. Optional services are available at extra charge. All services are paid for by the customer prior to launch.

Space System Development Agreement (SSDA). The SSDA provides launch and associated services to commercial customers on a delayed reimbursable basis for those customers that offer an important and unique use of space not yet available. The customer agrees to pay NASA for launch and associated services after the launch has occurred and the customer has begun to receive revenues resulting from the launch.

Joint Endeavor Agreement (JEA). The JEA is a cooperative agreement in which NASA and a private firm share common objectives and risk. JEAs are used primarily to encourage private ventures in space and to demonstrate the potential benefits of space technology. After a JEA is negotiated, the company develops the appropriate hardware to perform a selected space experi-

ment or technology demonstration in orbit at its own expense. NASA provides the flight opportunity at no cost to the company except for certain optional services outside the scope of services normally available to JEA experiments. The company is allowed to retain certain proprietary rights as a result of the JEA, particularly non-patentable information that yields a competitive edge in the eventual commercial marketing of any product which may result. NASA does require certain data to evaluate the significance of the results of the JEA and stipulates that any promising technologies be applied commercially within a reasonable amount of time or the results published. NASA retains rights to transfer the resulting proprietary data from a JEA to the public domain.

Small Self-Contained Payload (SSCP) Launch Services Agreement. The SSCP agreement provides conformance between NASA and the customer to fly SSCP experiments (known as "get-away special" (GAS) payloads on the Shuttle). The GAS program provides inexpensive access to the space environment for a wide variety of users. Users fly self-contained "GAS cans" in the payload bay of the Orbiter on a space available basis for a fixed price. An important aspect of this agreement is the absence of a NASA requirement for the GAS customer to indemnify the government against third party liability claims. This allows access to the GAS program for the widest and most diverse customer base possible, including schools and individuals.

Technical Exchange Agreement (TEA). In a TEA, NASA and a private sector company agree to fund their respective participation in a program. NASA gains the expertise of the company's private research capabilities and in turn, allows the company access to NASA research and facilities. NASA facilities such as wind tunnels, microgravity drop tubes, and aircraft flights are available for commercial use through TEAs.

Industrial Guest Investigator (IGI) Agreement. An IGI agreement provides the terms for an individual from private industry to cooperate with a NASA-sponsored principal investigator on a space research project. The IGI collaborates with NASA at the company's expense and becomes a member of the investigative team, bringing private sector expertise and insight to the research project.

Pricing

NASA is currently investigating various methods for pricing and allocating the resources of the Space Station base to commercial reimbursable users as well as science, technology, and cooperative commercial users. A potential component of this policy will be the use of mechanisms which allow users to select priority levels for delivery of Station resources. In addition to recovering government-funded Station costs, Station resource prices might reflect the user's evaluation of benefits or willingness to pay. The pricing policy may also allow for the long term commitment of prioritized resources to users in such a manner as to allow and encourage efficient use and voluntary exchanges of Station resources among users.

When pricing policy is finalized, it will be published as a separate document. See Appendix I for more information on Program-to-user documentation.

IV. SPACE STATION OPERATIONS AND USER INTEGRATION

The Space Station Program is committed to developing manageable and safe procedures that promote the basic goal of productive and flexible operations for the Space Station's user community. Space Station operations planning processes are currently being defined. The Space Station Operations Task Force (OTF) developed an operations framework which meets the Program objectives of safe and user-friendly operations, supports international participation in the operation of the Station, and addresses long term issues for furthering science and technology development. The overview of the user integration process precested here has been adapted from the OTF's report and describes the organizations and strategy for user selection and integrating user requirements and payloads into the Space Station Program.

User integration scenario

The user integration scenario describes the proposed flow of activities and milestones for integrating an investigator's payload onto the manned base of the Space Station. The operations concept for platform integration is similar, but the differences are not discussed here. The integration process is designed to be "user-friendly" to accommodate the divergent needs of users from different functional and demographic groups. This scenario depicts activities likely to be encountered by users of U.S. Space Station resources. The Partners will select and integrate users of their resources according to their own policies.

The procedures described below are typical of a "standard" integration cycle. A certain percentage of the Program's capabilities will be reserved for quick-integration (so-called "quick is beautiful") payloads, which require expeditious launch to respond to a unique or short-lived research opportunity. Information about the various opportunities for quick integration can be obtained from the Office of Space Station.

Space Station Resource Distribution

User integration begins with the distribution of the Station's resources among the Partners and the NASA user sponsors. A control board, chaired by NASA and staffed by NASA and the Partners, will be responsible for dividing the Station resources available to users (as opposed to the resources required to maintain the Station and crew).

Each Partner will be free to select users as it sees fit within the resource envelope allotted to them. In the U.S., a Space Station User Board (SSUB), consisting of representatives of each class of user, will divide the U.S. allocation among the various disciplines that use the Station.

Proposal review

Any user who is interested in utilizing the Space Station Program is encouraged to submit a formal proposal. Each proposal will then undergo a series of reviews to determine its compatibility with the sponsoring office's goals and resource allocation, and the objectives and constraints of the Program. Reimbursable users will be reviewed only to ensure that the proposed payload will not contravene any limitations placed on the Space Station Program. The SSUB will review the payloads that have passed this milestone, and then gather additional information for a feasibility assessment.

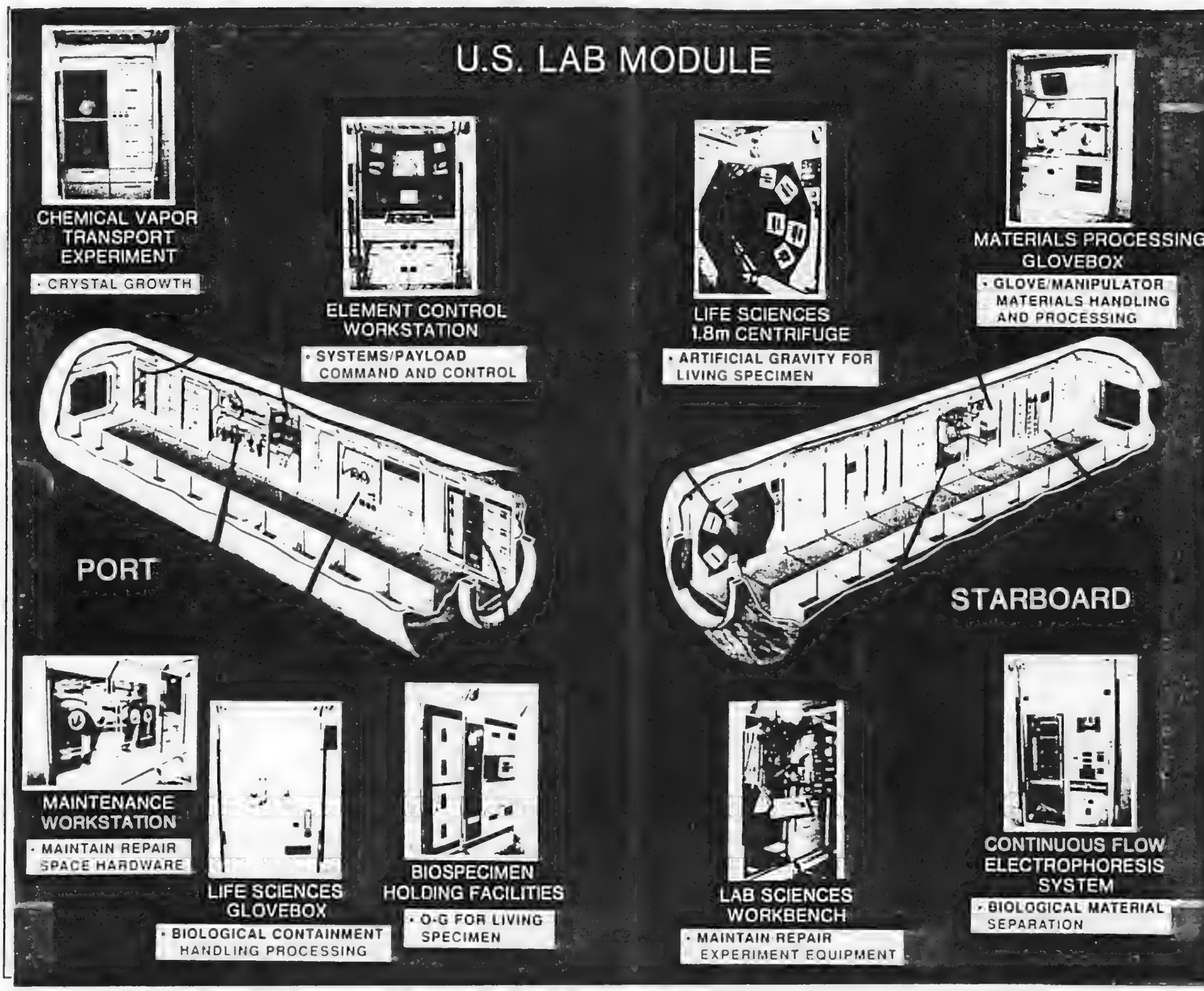
Institutional operations offices will support the feasibility assessment to verify that the candidate payload will meet crew interface and safety standards and can be supported by the logistics, transportation and information systems. The SSUB

will then give the results of the feasibility review back to the sponsors, who will then formally select their payloads.

Request for flight

Following selection, the user prepares a Request for Flight (RFF), which will be similar to the STS Form 1628 (formerly called STS Form 100). The RFF outlines the user's anticipated demand for Station resources, the location of the payload on the Station, the desired flight dates, and payload priority. For commercial users, the RFF will also cover insurance provisions, the involvement of a payload scientist on board the Station, and any other issues which must be considered to permit planning and pricing of the activities. Based on this information, the sponsor will provide the user with a "best effort" commitment to the costs which the user must pay for access to the Station and its resources. In turn, the user will review the restictions and requirements that the Program will impose on the payload and its activities.

After the user and the sponsor sign off on the terms of the RFF, the form is



The U.S. laboratory module will have numerous accommodations to support a wide variety of scientific experimentation.

submitted to the SSUB for review. The SSUB examines the payloads selected by each class of user to ensure that the requirements of the total complement selected by each class are compatible and do not exceed the allocated resources. Payloads accepted at this point are then forwarded for consolidation with payloads approved by the other Space Station Partners. After final approval, all payloads will be entered in the Space Station five-year plan, giving the users a commitment to fly on the Station during a particular calendar quarter, though a specific date will not be specified.

Payload assessment and development planning

After the user has received a flight commitment, the sponsor will initiate payload development. At this point, the user will become a member of the Space Station User's Working Group, which represents the interests of all the users in the program.

At the same time, the user will be assigned a Payload Accommodation Manager (PAM), whose primary responsibility is to serve as the user's interface with the Program. PAMs will be highly qualified individuals, generally having a utilization-oriented background. They will be selected from the various NASA offices, NASA Centers, or the Partner support centers.

The PAM will be the user's single point of contact and will provide all required support to the user from the Space Station Program. The PAM's responsibilities include:

- Coordination of user requirements with Space Station element accommodations (including Partner-provided elements) and transportation and data systems offices
- Support of the activities at the payload development center
- Coordination of the development of Program-provided payload support hardware and software
- Coordination of measures to protect proprietary operations and information
- Support of payload integration activities
- Monitoring of payload resource utilization.

The PAM will also work with the user to develop formal user-to-Program documentation, such as the Payload Integration Plan (PIP), specifying the user's requirements and responsibilities for all phases of his involvement with the Program. The user's sponsor may assign an experiment development engineer to assist the investigator in designing and developing his payload. The user may also be assigned to a Science and Technology (S&T) Center for development support. S&T Centers will be established by the NASA offices and other sponsors to provide expertise in a particular area of Space Station utilization.

Design and safety reviews

NASA design and safety practices are fairly standard. A number of formal reviews are held during the instrument development phase. The design is controlled by specifications that will contain all of the requirements to which the design must respond.

The PAM's first responsibility will be to arrange for an initial (Phase Zero) safety review. Then the user, the sponsor and the PAM work together to assemble a development plan for the user's payload and the associated operations procedures and ground facilities. While an S&T Center may provide support, the PAM will monitor payload development to ensure compliance with standards and schedules.

It is Program policy to encourage all involved user and Program personnel to

report any problems and concerns promptly. Failure to do so may impact experiment support or have consequences on future support to the user.

Ground facility development

In addition to developing the payload, an investigator will need access to ground facilities to develop procedures for monitoring and operating the payload during flight. Many payloads will be operated by telescience, the process by which users on the ground directly interact with their remotely located payload.

Most users will be assigned to a Discipline Operations Center (DOC) by their sponsor or S&T Center. The DOC will coordinate the ground-based operations of its members during flight preparation and execution. If desired, users may build their own facility that will link up with the Station and be coordinated with other users via the DOC. Users who operate their payloads in or via a DOC will be referred to as "discipline users". Some users, particularly commercial proprietary users, may develop independent facilities that interact with the Station directly. These users will be called "direct users".

Integration of user's requirements into the TOP

Approximately 24 months before flight (at or near the payload preliminary design review), the payload will be assigned to a specific flight increment within the Tactical Operations Plan (TOP). The TOP covers a two year period and manifests users to specific flight increments (a flight increment is the period of time between STS visits to the manned base or between OMV servicing visits to a platform).

To be entered in the TOP, the user must define his Station requirements to the point where they can be coordinated with those of other users. The PAM will arrange for the next series of reviews, including a Phase One safety review, with each of the operations offices involved in supporting the user's payload. Once this round of assessment has taken place, the payload will be assigned to a new flight increment within the TOP.

A user must enter the Program planning process at this point if the payload requires a "complete" range of Station resources. This is particularly important if the payload requires significant crew time or power. Because of planning constraints, quick-integration users who enter the increment after this point will be restricted with regard to resources and the range of payloads they can implement. For instance, crew specialization and composition is determined soon after the release of the TOP, and crew user training begins at approximately 18 months before launch; as a result, major new crew operations cannot be added to the operations plans once the crew has been assigned and detailed.

Increment operations planning

Once the TOP has been approved, an increment change manager is assigned to oversee all of the planning, operation and integration activities involved in implementing a specific increment. The TOP will assign primary Station operations, maintenance and servicing activities to weeks within the flight increment, but will not provide detailed timelines or operations directions. It is the increment change manager's responsibility to see that these timelines and operations directives are developed.

Once a user has been assigned to a particular flight increment, he joins other investigators for that increment in an investigator's working group (IWG), which will be directed by an increment scientist. This group will work together to participate in execution-level planning based on the contents of the TOP. Although the IWG will consist of representatives from each user, in practice the majority of these coordination activities will be handled by the IWG increment scientist and

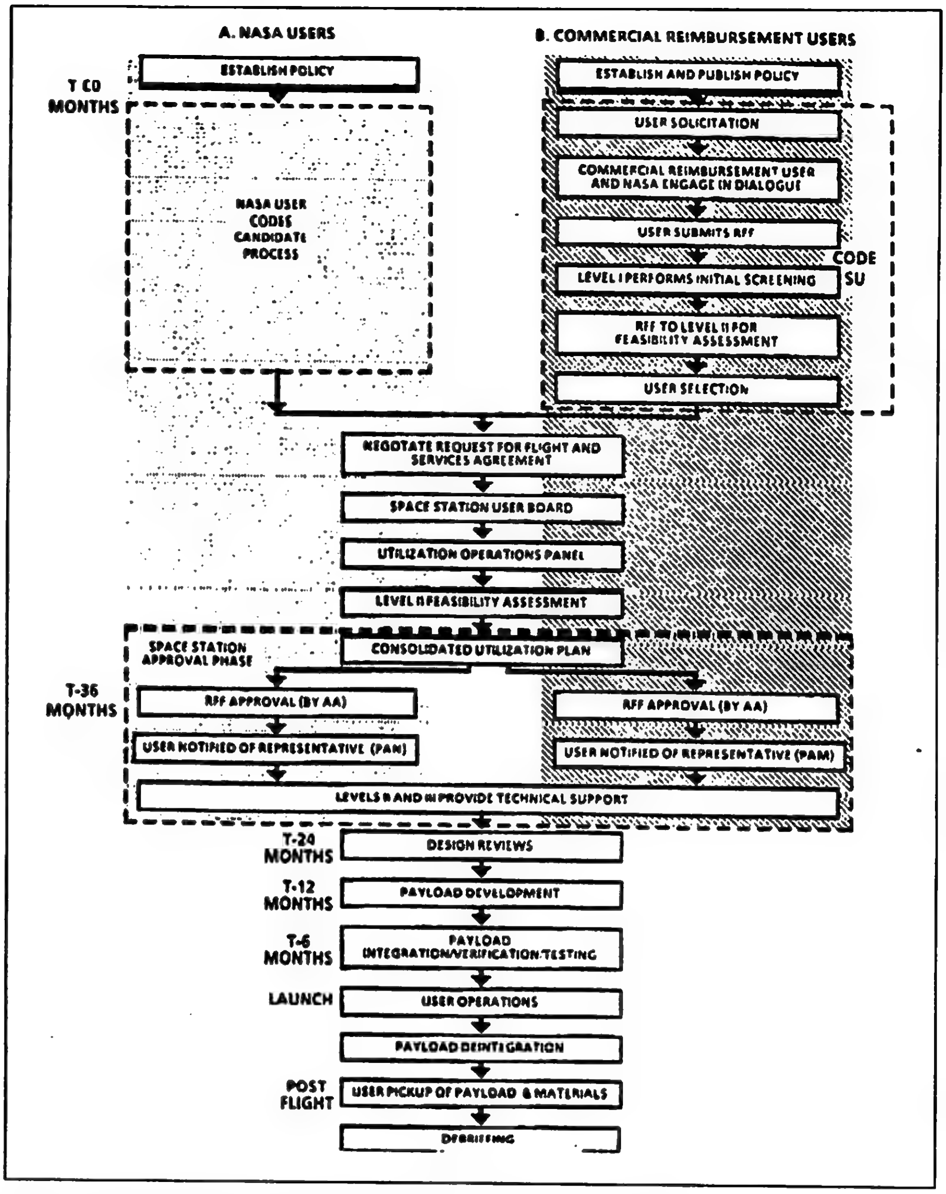
the PAMs on behalf of the users.

Flight increment planning process

The user's payload must pass the preliminary design review and the Phase Two payload and safety review before undergoing a final operations assessment by all offices involved in accommodating the payload. The user's PAM and sponsor organization will support this assessment as required.

After the final operations assessment, the user will be ready to participate in the development of flight increment plans. The plan identifies specific scheduling constraints, crew skills and work load, and specific maintenance and servicing requirements. It also assigns the user a particular envelope of resources, such as crew time, data transmission, power, and data storage.

The planning process continues until the flight increment plan is finalized one year prior to the launch that initiates the flight increment. The plan then becomes the basis for the increment operations planning process. These plans are refined continuously until six weeks prior to the launch; changes occurring after this time are considered part of the "replanning" process that continues throughout the increment.



Overview of the Space Station user integration process.

Training requirements

The user is responsible for training the Station crew and NASA ground personnel to operate and maintain the payload. The user must explain the payload's scientific background and experiment objectives, familiarize the crew and ground personnel with the experiment systems, and teach the crew the operations plan for the payload. The user will also be responsible for training any necessary staff to operate the payload from the ground.

These activities will occur at the investigator's site and the ground facility. If the user will be providing a payload scientist (a user-provided astronaut), this person will be instrumental in the training function. In some cases, the payload's NASA sponsor may coordinate training activities.

Selected users with particularly complex payload execution requirements will be asked to deliver two high-fidelity copies of the payload and any related software to the Program for use in simulation and training activities. These models will "migrate" as needed through Program simulators.

The user will also undergo training provided by the Program, along with the

crew and other users. This training will familiarize the user with the command procedures for normal and contingency situations, describe the transaction management system used to ensure that user operations do not conflict with one another, and verify that the ground facility is operational prior to launch. If a payload scientist will operate the payload on the Station, this individual must be trained in Station habitation, health maintenance, and crew systems operation.

Payload integration and logistics operations

Prior to launch, the user's payload must be integrated into experiment racks or other carriers and the racks into one of the logistics modules or external pallets. Payloads may be integrated into racks either at the S&T Center which has supported the user, at the launch site, or at integration facilities provided by the Partners in the U.S. or abroad. The location of rack integration depends both on the terms of the PIP and on the location where the payload will be installed on the Station.

The Logistics Operations Office will make storage and preservation facilities available to the user according to terms established in the PIP. The facilities will support user payloads from the time they are delivered to the launch site until launch. If the user will be sending any supplies or spares along with the payload, this must also be coordinated with the Logistics Operations Office.

Pre-launch processing

Once the racks and other equipment have been integrated into the logistics module or pallet, the Program hands the module and any other carriers over to NASA's Office of Space Flight (OSF). OSF integrates the modules into the Shuttle or other launch vehicle and is responsible for the module from that time until it has been off-loaded to the Station. If the user requires late access to the payload (for feeding of laboratory specimens, handling of fragile substances, or last-minute loading of experiments), the PAM will arrange for that access. OSF is responsible for overseeing and executing late access requirements.

On-orbit checkout and verification

After the launch vehicle has docked with the Station and the logistics module has been unloaded, the Space Station crew will install the new racks and equipment. Once the user's payload is in place, it must undergo an on-orbit checkout to ensure that it is functioning properly. The order in which systems and payloads are checked out is determined prior to launch as part of the flight increment planning process. From the ground facility, the user will issue the commands required to complete checkout and verification, and will oversee the activities of the crew. If the user desires, the crew will perform the entire payload checkout procedure, freeing the user from the responsibility. Once the payload and systems checkouts have been completed, increment operations can begin.

Daily replanning process

The increment operations plans provide a timeline for the entire increment. However, detailed crew integration planning is provided only for the periods involving launch vehicle transfer operations or other activities requiring complex crew/ground interaction. Planning for routine operations during the increment will be coordinated on a daily or weekly basis by the planning teams. If there are any changes to the planned resource envelope, the investigator's working group coordinates changes to individual user plans. Under the direction of the increment scientist, user representatives will negotiate new resource and time envelopes for integration with Station systems replanning.

Inflight operations

While the payload is in orbit, the user must send commands for operations from the ground facility and oversee any actions taken by the Station crew. The user is also responsible for monitoring the status of the payload to ensure that it remains in safe operating mode. The Payload Operations Integration Center (POIC) will also monitor all user operations to ensure that they conform to the operations plan and to detect any changes or trends that could be hazardous or detrimental to the Station or other user operations.

The user will receive data from the payload while it is operating on orbit. This data will allow the user to determine whether the payload is functioning as planned, or whether changes in hardware, specimens, or plans is necessary. Requests for changes or additional resources can be relayed through the IWG as part of the daily replanning process.

It is the sole responsibility of the user to coordinate correction of an inflight failure, unless Station systems are suspected of causing the failure. The user may develop a payload inflight servicing plan prior to flight which must be performed by the crew. Any changes in the user's operations must be approved within the IWG and by the POIC prior to implementation.

Continuing operations

If the user's payload will operate for more than one increment, any changes in resource requirement must be included in the plan for the next increment. These changes must be approved before the start of the next increment.

Payload shutdown

When the user's operations have ended and the payload is to be returned to Earth, it must be shut down for safe rack deintegration. Shutdown is accomplished through ground commands and by crew actions if dismantling is required. It is the responsibility of the user to ensure that payload specimens or results remain in good condition.

On-orbit storage

Some payloads will operate only periodically. Storage area on the Station is severely limited, making storage of such payloads a problem. Currently, the only way to make periodic observations is to fly the instrument, return it to Earth, then fly it again as necessary. Since this is not a cost effective method for larger payloads, the possibility of leaving inactive payloads on the Station is being considered. An on-orbit material retention policy will be used to determine what materials may be left on-orbit to provide value or utility for future missions. Materials left on-orbit must be contained and not be a source of hazard or contamination to Station operations.

Payload pickup

Following the return of the payload to Earth, the user will pick up the payload at the original integration site, or will have the payload delivered to the development site. If the user requires, the Program will allow the user to retrieve the payload at the STS landing site. The timing, location and service fees associated with the pickup, as well as the means of transportation, will be negotiated as part of the PIP.

User debriefing

When the user's operations for a given payload have been completed, the user will undergo a debriefing involving the sponsor, the PAM, and the Program offices involved in accommodating the payload. Information gathered during the debriefing will be used by the Program to improve its services and interfaces, and

by the sponsor to determine the utility of the Station in fulfilling its goals.

Post-mission reports

The final requirement placed on NASA-funded investigators is the submittal of a formal report describing the results that were found for the experiment and the problems encountered during the mission. The results of an experiment may identify problems that the investigator would like to pursue on future missions or other areas of investigation for followup studies. New proposals may be submitted for a reflight of an experiment or for any other type of proposal an investigator may conceive. NASA continues to support each investigator throughout the various developmental and operational phases to ensure that experiments capture the greatest possible scientific return. Problem reports will help to point out areas where the facilities or interfaces can be improved.

Data Archiving

Some users (particularly science and technology users) will archive data to make it available to other investigators within their discipline. Unless otherwise negotiated as part of the PIP, archiving of payload data will be handled by the sponsoring organization.

APPENDICES

Appendix 1. Program-to-User Documentation

The Space Station Program is a large and complex program which will generate a large amount of documentation. Users must become familiar with much of this documentation in order to make proposals, design and build payloads, specify training and operational requirements, and perform many other functions to meet their investigative objectives.

In order to facilitate a smooth flow of information from the Program to users, all Space Station Program-to-user Space Station documents fit into a single, unified structure which is loosely tied to the involvement of the user as he progresses to increasing degrees of involvement with the Program. The documents are broken into several categories. *This* document fits into Category 2, as described below.

Category — Application

1 **General Public Information** — Wide distribution glossy material for anyone having an interest in the Space Station Program.

2 **General Solicitation of User Interest** — Marketing-type information for soliciting interest from all categories of possible users.

3 **Programmatic Utilization** — Information needed to ascertain the utility and competitiveness of the Station for a particular application. Permits a prospective user to make engineering, financial and management determinations of whether to seek Space Station resources for the performance of a proposed activity and to accurately estimate the complexity, schedule and resources required to operate a payload using the Space Station.

4 **Technical Utilization** — Information required to develop, test and certify payload equipment, get it launched, operated aboard the Station, and returned.

5 **Payload-Specific** — All joint user/Program documentation required to plan and conduct successful and contingency payload operations during a mission interval.

6 **User-to-Program** — Documents the Program will require from the user at

various stages of the user's involvement with the Program to properly integrate and operate the user's payload.

7 **Experience** – Questionnaires and narratives by Program personnel who interface with users describing their mission experience, with a focus on problems, how they occurred, how they were resolved, and how such problems might be mitigated or prevented in the future. This category will contain Lessons Learned reports (completed by Program personnel or user sponsors from each mission interval design process). In addition, the actual operational execution of the mission plan on the Space Station will be published by the Program as an aid to future users.

The above categories are in general order of increasing detail, but are not strictly in the order of when each set of documentation would be provided to a specific user or prospective user. For example, some mission-specific documentation, such as a current payload manifest, might be given to a user before detailed interface specifications.

Program-to-user documentation is available from two sources: a centralized repository of printed documents where all publications pertaining to the Space Station may be ordered, and electronically; documentation is indexed and available for computer subject searching via the Space Station Technical Management and Information System (TMIS).

As a next step in the involvement of users with the Space Station Program, the following documents may be helpful to users to determine specific Program policy and technical information:

- *Space Station Users' Guide: Management and Policy.* A detailed description of the Program's organization and summaries of the roles and responsibilities of each major part of the Program. In addition, this document will contain information on the payload developer's participation in Operations and Working Groups.
- *Space Station Users' Guide: Technical.* Provides prospective users of the Space Station with technical information on Space Station performance capabilities to assist with the generation of payload proposals and assessment of the Station's technical capabilities to support a given payload.
- *Space Station Users' Guide: Reimbursement.* Describes the methods for determining the cost of Space Station resources and services.

Appendix 2. Acronym list

This acronym list is intended to be a comprehensive list of acronyms users might encounter during their involvement with the Space Station Program. Not all of the acronyms listed were used in this document.

A&I ...... Assembly and installation
A&R ..... Automation and robotics
AACS ..... Attitude and articulation control subsystem
ACS ...... Attitude control system
ADS ...... Attitude determination system
ALT ...... Radar altimiter
APC ...... Autonomous payload controller
ARC ...... Ames Research Center
ARS ...... Air revitalization system
ASE ...... Airborne support equipment

ASEB .....Aeronautics and Space Engineering Board
ATP ......Authority to proceed
BIT ....Built-in test
BITE ......Built-in test equipment
BP ....Biological processing
C3 ....Command, control, and communications
C&T ......Communications and tracking
CAP ......Crew activity plan
CE&IS ....Combined elements and integrated systems
CELSS ....Closed environmental life support system
CERV......Crew emergency return vehicle
CFE ......Customer furnished equipment
CFS ....Cryogenic fluid storage
CG ....Center of gravity
CHX ......Cabin heat exchanger
CIL ....Critical items list
CMG .....Control movement gyro
COF ......Construction of facility
COP ......Co-orbiting Platform
CP ....Containerless processing
CSR ......Customer support room
D&C ......Display and control
DDU ......Data display unit
DMS ......Data management system
DOMSAT .Domestic satellite
DSN ......Deep Space Network
EAC ......Experiment apparatus container
ECLSS ....Environmental control and life support system
ECS.......Environment control system
EDRS .....European Data Relay Satellite
ELM ......Experiment Logistics Module
EM ....Electromagnetic
EMU .....Extravehicular mobility unit
EOS ......Earth Observing System
EOS ......Electrophoresis operation in space
EPDS .....Electrical power distribution system
EPS ....Electrical power system
ESA ......European Space Agency
ESD ......Electrostatic discharge
EVA ......Extravehicular activity
FAB ......Flight assignment baseline
FDF ......Flight data file
FEL ......First element launch
FI.........Flight increment
FIP ....Flight increment plan
FMEA ....Failure modes and effects analysis

FOSA ..... Flight operations support annex
FSE ...... Flight support equipment
FSSR ..... Flight systems software requirements
FTS .... Flight telerobotic servicer
GAS ...... Get-away special
GEO ...... Geosynchronous Earth orbit
GFE ...... Government-furnished equipment
GN&C .... Guidance, navigation and control
GPC ...... General purpose computer
GPS ...... Global positioning system
GSE ...... Ground support equipment
GSFC ..... Goddard Space Flight Center
GSTDN ... Ground Satellite Tracking Data Network
HSO ...... Habitation and Station operations
ICD ...... Interface control document
IDD ...... Interface definition document
IDM ...... Information and data management
IGA ...... International governmental agreement
IGSE ..... Instrumentational ground support equipment
IIA .... Instrument interface agreement
ILS .... Integrated logistics support (or system)
ILSP ...... Integrated logistics support plan
IMU ...... Inertial measuring unit
IOC ...... Initial operational capability
IPS .... Instrument pointing system
IR .... Infrared
IRU ...... IVA replacement unit
ISF .... Industrial Space Facility
IUS .... Inertial upper stage
IVA ...... Intravehicular activity
JDTRS .... Japanese Data Tracking and Relay Satellite
JEA ...... Joint endeavor agreement
JEM ...... Japanese Experiment Module
JLM ...... Japanese Logistics Module
JSC .... Johnson Space Center
KSC ...... Kennedy Space Center
KW .... Kilowatt
LaRC ..... Langley Research Center
LeRC ..... Lewis Research Center
LCC ...... Launch control center
LEO ...... Low-Earth orbit
LGM ..... Logistics module
LRU ...... Line replaceable unit
LSSM ..... Launch Site Support Manager
LSSP ..... Launch site support plan
MCC ..... Mission Control Center (JSC)

MED .....Momentum exchange device
MET ......Mission elapsed time
MFR ......Manipulator foot restraint
MMD .....Mobile (servicing center) maintenance depot
MMS ......Multi-mission modular spacecraft
MMU .....Manned maneuvering unit
MOSST ...(Canadian) Ministry of State for Science and Technology
MOU .....Memorandum of understanding
MPC ......Multiple payload carrier
MPS ....Materials processing in space
MRDB ....Mission Requirements Data Base
MRMS ....Mobile remote manipulator system
MSFC .....Marshall Space Flight Center
MSS ......Mobile servicing system
MTC ......Man-tended capability
MTFF .....Man-tended free-flyer
NASCOM .NASA communications
NASDA ...(Japanese) National Space Development Agency
NMI ......Nautical miles
NMI ......NASA management instruction
NSP ....Network signal processor
NSTS .....National Space Transportation System
OAST .....Office of Aeronautics and Space Technology
OFT ......Orbital flight test
OMCF ....Orbiter maintenance and checkout facility
OMS ......Operations management system
OMV .....Orbital maneuvering vehicle
ORU ......Orbital replacement unit
OSE ......Orbital support equipment
OSSA .....Office of Space Science and Applications
OTV ......Orbital transfer vehicle
PACE .....Physics and chemistry experiments
PGSE .....Payload ground support equipment
PI ....Payload integrator
PI ....Principal investigator
PIA ....Program initiation agreement
PIM ....Payload Integration Manager
PIP ....Payload integration plan
PL ....Payload
PLSS ......Portable life support system
PMC ......Permanent manned capability
PMP ......Payload mission plan
PMS ......Program management system
POIC .....Payload Operations Integration Center
POCC .....Payload Operations Control Center
POP ......Program operating plan

POP ...... Polar-orbiting Platform
PP .... Polar Platform
PPF .... Payload processing facility
PPS .... Payload positioning system
PSCN ..... Program Support Communications Network
RCS ...... Reaction control system
RMS ...... Remote manipulator system
SAIS ...... Science and Application Information System
SE&I ..... Systems engineering and integration
SIP .... Standard interface panel
SL .... Spacelab
SLF .... Shuttle landing facility
SMAP .... Software management and assurance program
SPDM .... Special purpose dexterous manipulator
SPIAP .... Shuttle payload integration activities plan
SR&QA ... Safety, reliability and quality assurance
SRB ...... Solid rocket booster
SS .... Space Station (usually manned base)
SSC .... Space Station complex (SS, MTFFs and Platforms)
SSDS ..... Space Station data system
SSE .... Space Station Element
SSIS ...... Space Station Information System
SSOC ..... Space Station Operations Center
SSP .... Space Station Program
SSP .... Standard switch panel
SSPE ..... Space Station Program Element
SSPO ..... Space Station Program Office
SSRMS ... Space Station remote manipulator system
SSSC ...... Space Station Support Center
SSSF ...... Space Station Support Facility
SSSP ...... Space Station safety program
SSST ...... Space Station system trainer
STA ...... (Japanese) Science and Technology Agency
STDN ..... Satellite tracking and data network
STS .... Space Transportation System
TBD ...... To be determined
TBS ...... To be supplied
TCS ...... Thermal control system
TDAS ..... Tracking and data acquisition satellite
TDASS ... Tracking and data acquisition satellite system
TDL ...... Transparent data link
TDR ...... Tracking data relay
TDRS ..... Tracking and data relay satellite
TDRSS .... tracking and data relay satellite system
TMIS ..... Technical and Management Information System
TRS ...... Telerobotic servicer

VAB ...... Vehicle assembly building
VAFB ..... Vandenberg Air Force Base
WP .... Work package
ZPS .... Zero-prebreathe spacesuit

Appendix 3. Glossary

Attached payloads: Payloads located on the Space Station base structure outside the pressurized modules.

Automation: The ability to carry out a pre-designated function or series of actions, after being initiated by an external stimulus, without the necessity of continuous human intervention.

Co-orbit: In the same, or near same, Earth orbit as another object, particularly with respect to the orbit period. For the Space Station Program, co-orbiting object can be assumed to have the same period and eccentricity, but a slightly different right ascension (i.e., perfect station-keeping ahead of or behind the Space Station).

Command and Control Zone: The traffic management zone within which the Space Station Crew serves as the primary control authority for all approaching and departing vehicles.

Commercial activities: Fully reimbursable use of NASA resources by the domestic industry.

Commercialization: Encouraging and facilitating domestic private sector applications of the products, knowledge or services resulting or deriving from space activities.

Control Zones: Specified regions around the Space Station base that define the operational boundaries for proximity operations, command and control, departure, rendezvous, co-orbiting satellites, non-co-orbiting satellites, and parking orbits.

Data Management System (DMS): The onboard portion of the overall Space Station Information System (SSIS).

Element: When spelled lower case (element), the common dictionary meaning. When capitalized (Element), a Space Station Element or Space Station Program Element.

Emergency: Any unexpected condition or occurrence that can pose an immediate threat to life and demands immediate corrective action.

European Space Agency (ESA): An organization headquartered in Paris which provides for and promotes, for exclusively peaceful purposes, cooperation among European states in space research and technology. ESA member states include Belgium, Denmark, France, Italy, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and the Federal Republic of Germany. Austria is an associate member.

Extravehicular Activity (EVA): Any operation performed by the crew outside the protective environment of the Space Station.

Flight Increment (FI): The period of time that a given set of users flies on the Station; the interval between Space Shuttle supply missions – roughly 45 days.

Flight Support Equipment (FSE): Equipment used for transport, handling, supporting and servicing flight hardware during transport to orbit using the STS and deployment of the flight hardware from the Orbiter. This equipment will be returned to the ground on the same or a subsequent flight.

Flight Telerobotic Servicer (FTS): A device attached to a Space Station manipulator or the OMV which interfaces with the payloads located on the Space Station base, or with payloads located on platforms or free-flyers, in order to allow for *in situ* servicing to be performed from remote locations.

Free-flyer: A free-flying, unmanned satellite which may be serviced by the Space Station system but is not associated with one of the Platforms.

Intra-vehicular Activity (IVA): Any task performed by crewmembers inside the Space Station.

Low-Earth Orbit (LEO): TBD

Maintenance: Modification of a payload, after initial delivery, to correct faults, improve performance, or adapt it to a changed environment.

Microgravity: The low acceleration level experienced in low-Earth orbit; less than one-millionth of normal Earth gravity.

Orbital Maneuvering Vehicle (OMV): A reusable, remote controlled free-flying propulsive vehicle capable of transporting payloads between LEO trajectories. It is designed to be operated from either the Station or the Space Shuttle.

Orbital Replaceable Unit (ORU): The lowest level of component or subsystem hardware that can be removed and replaced while on orbit.

Orbital Transfer Vehicle (OTV): A reusable, remote controlled free-flying propulsive vehicle capable of hauling large payloads up to and back from high altitudes.

Partner: TBD

Payload: a specific complement of instruments, space equipment, and support hardware carried into space to accomplish a mission or discrete activity in space.

Phase I: The first phase of the Space Station Program, during which permanent, manned capability is achieved. It includes the on-orbit installation of the horizontal (transverse) boom, photovoltaic arrays for the generation of 75 kw of power, the Flight Telerobotic Servicer, Four pressurized modules, the first increment of the Mobile Servicing System, Resource nodes, and two polar Platforms.

Phase II: The second stage of the Space Station Program, during which the solar dynamic power system, the upper and lower booms, the final increment of the Mobile Servicing System, and the co-orbiting Platform Elements are added to the Phase I Space Station.

Platform: An unmanned, orbiting, multi-use structure capable of supplying limited utilities to changeable payloads and dependent upon the Space Station system for its long-term operation.

Privatization: Shifting to the private sector for the acquisition of goods or services required to conduct NASA programs.

Proximity Operations: Those operations performed when vehicles are close enough that their relative motion may be approximated as linear with little loss in performance.

Robotics: The technology by which machines perform all aspects of an action, including sensing, analysis, planning, direction and control, and effecting and manipulation, with human supervision.

Safe Haven: A concept where the Space Station provides a temporary shelter for the Station crew for protection against harm during emergencies, including situations internal to the Station (such as a fire in a module) and external (such as a large solar flare).

Servicing: Activities performed on items or equipment which facilitate or enhance support to operational objectives.

Space Station: The portion of the Space Station Program intended for permanent habitability and any booms, payloads, or other structures attached to it, exclusive of unmanned platforms, free-flyers, and other spacecraft temporarily attached to the Station for servicing. Synonymous with manned base.

Space Station Element (SSE): Any of the manned modules, resource nodes,

airlocks, logistics modules, truss elements, Mobile Transporter, Flight Telerobotic Servicer, attached payload accommodation facilities, servicing facility, solar power modules, propulsion modules, unpressurized logistics carrier, Mobile Servicing System, or MSS Maintenance Depot. See Element.

Space Station Program Element (SSPE): Any of the manned Station base, a co-orbiting Platform, or a polar Platform. See Element.

Telescience: the direct, iterative and distributed interaction of remote users with their instruments, data bases, specimens and data handling facilities, especially where remote operations are essential.

Terrestrial Space: The area from the base of the ionosphere (about 60 km above the Earth's surface) to the boundary of the magnetosphere beyond which interplanetary space is unaffected by the Earth (about 95,000 km in the sunward direction to several times this distance in the anti-sunward direction).

Tracking and Data Relay Satellite System (TDRSS): A system of Earth-based receiving stations and geostationary satellites which relay data from the Space Station and Shuttle orbiters to Earth.

User: any individual, group or agency responsible for the development or operation of a payload utilizing an element of the Space Station Program.

Appendix 4. Contact list

For more information regarding the Space Station, its resources and capabilities, and other general questions, contact:

Office of Space Station
Space Station Program Office
Reston VA Zip-TBD
(703) 999-9999

For sponsorship information, contact the Office of Space Station or the an appropriate NASA sponsor:

Office of Space Science and Applications
National Aeronautics and Space Administration
Washington DC 20546

Office of Aeronautics and Space Technology
National Aeronautics and Space Administration
Washington DC 20546

Office of Commercial Programs
National Aeronautics and Space Administration
Washington DC 20546

For information regarding sponsorship from one of the Program's international Partners, contact the appropriate Partner office:

ESA
TBD

Japan
National Space Development Agency of Japan
World Trade Center Building
4-1, Hamamatsu-cho 2-chome, Minato-ku Tokyo 105 Japan
Phone: 81-3-435-6111
Fax: 81-3-433-0796
Telex: J28424(AAB: NASDA J28424)

Canada
TBD

For questions regarding the science activities and objectives of the Space Station, contact:

Space Station Project Scientist
Space Station Program Office
Reston VA Zip-TBD
(703) 999-9999

Appendix 5. Index

TBD – to be indexed after all edits are complete